

LECTURES HISTOLOGY,

DELIVERED AT THE
ROYAL COLLEGE OF SURGEONS OF ENGLAND,
IN THE SESSION 1850—51.

ELEMENTARY TISSUES OF PLANTS AND ANIMALS.

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ILLUSTRATED BY ONE HUNDRED AND FIFTY-NINE WOOD-CUTS.

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P R E F A C E.



HISTOLOGY OF VEGETABLES.

LECTURE I.

HISTOLOGY,* the science of the minute structure of the organs of animals and plants, may be truly said to be the creation of the present century; some glimpses, however, of organic structure had been obtained by the earlier observers, Leeuwenhoek, Malpighi, Hooke, Grew, and others; but these, for the most part, consisted of unconnected observations, from which it was impossible to educe any of the general laws of formation and development. The microscope, except as a mere toy, fell into disuse during the greater part of the eighteenth century; nor was it until within the last that the instrument was rendered capable of magnifying power to such an extent as to reveal the structure of the minutest parts of the vegetable kingdom.

One of the primary and most invaluable results brought out by elaborate examination of the minute structures of organized beings is, that even a closer unity of organization exists among these structures than is found among the larger organs of animals, visible to the unassisted eye. While little, if any, anatomical analogy is discoverable between the larger parts of animals and plants, the strongest ties of organization are demonstrated by the microscope; and it is found, as we shall hereafter see, that an unity of plan in structure and development, may be traced throughout the organic world.

In organized beings, nature works out her most secret processes by structures far too minute for observation, unless with the assistance of the microscope. Hence we find that our best modern works on human and comparative physiology, are filled with descriptions and illustrations of minute structure. The processes of secretion, of nutrition, of generation, nay, even the mysterious actions of the brain and nervous system, unintelligible, except in their results, by the gross means of investigation heretofore employed, are now being gradually evolved by the labours of microscopic physiologists. Nay, more, what is of greater importance, having discovered the healthy struct

P R E F A C E.

ALTHOUGH the Lectures contained in the following pages have already appeared in the "Medical Times" for 1851, it has been thought advisable to publish them in a separate form, and for this purpose they have been carefully revised, and a considerable amount of new matter has been added.

The last two Lectures have been omitted in this volume, but will be included in a subsequent one, as they relate to the Structure of the Skeleton of Invertebrate Animals, which formed the subject of the Course of Lectures for 1851—52.

The preparations exhibited, were, with few exceptions, those described in the first volume of the Histological Catalogue, to which work the Author would refer those of his readers, who may be desirous of having a more detailed account of the individual specimens.

The Author begs to tender his best thanks to his friend, Dr. P. B. Ayres, for much valuable assistance during the progress of the work.

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greatest possible aid is thus afforded to scientific medicine in the diagnosis of diseases, that in many cases would be undistinguishable without the assistance of this instrument. It would be easy to quote numerous examples of the utility of the microscope, in establishing a sound pathology, but it will suffice for my present purpose to cite urinary deposits and tumours, the nature of which is most readily determined by microscopic examination.

Among those who have employed the microscope not only with the greatest assiduity, but with the utmost benefit, both to science and their fellow-creatures, have been the members of the medical profession. It would be foreign to my purpose to point out the many advantages to be derived from a knowledge of the intimate structure of organized bodies, in health and disease, as this is amply demonstrated, not only by the publications of the day, but also by the increasing demand in all parts of the globe for this kind of information.

However striking the difference between an animal and a plant may seem at first sight in the higher groups, a more extended examination shows that animals and plants gradually approach each other as we descend in the scale until they meet in a common centre—the simple or individual cell. At this point, all means of distinction between the vegetable and animal organism end, and no feature exists which, in the present state of science, can enable even the most distinguished microscopist to determine to which of

the two kingdoms the individual cell belongs, since it possesses characters common to both. Zoologists, botanists, and chemists, have, each and all, bestowed the labour of years on the solution of this question, and have endeavoured, but without success, to establish some decisive character by which animals and plants may be distinguished.

In the earlier periods of natural history, the power of spontaneous motility, and the presence of a stomach, were considered as the distinguishing characteristics of an animal. It is now well known that certain confervæ possess the power of locomotion, while the sponges and some allied families of animals, are destitute of both these attributes. Chemists in former times, considered the presence of nitrogen as a distinct proof of the animal character of the tissues containing this element; but more modern researches have demonstrated that nitrogenized matter is a necessary constituent of the growing parts of plants. Histological inquiry, as I have already stated, has proved equally incapable of solving this question; the appeal to the higher powers of the microscope having rendered the problem more complex by the discovery of a *common* in place of a *distinctive* character; namely, the primary cell, or starting point for all organic beings.

It being demonstrated by histological examination that the cell is the primordial condition of the animal and the plant, it is essentially necessary that the student of histology should be himself familiar with

the primary elements discoverable in both these grand divisions of the organic world.

The vegetable kingdom is divided by the philosophical botanist into two great classes, the *cellulares* and the *vasculares*; the former containing the lowest, and therefore the least complicated forms. In this class the *fungi*, *algæ* and *lichens*, are composed of simple cells alone, occasionally elongated or otherwise modified in shape in the higher types of each order. The lowest form in each of these orders is a simple globular or ovoid cell. As we proceed, two or more cells are united in a definite form. . Still further development occurs in higher groups until we find distinct organs, which, in the highest of the *algæ* and *lichens* bear a striking similitude to the leaves and seed-vessels of the vascular or flowering plants. Some orders of *algæ*, the *Desmidiæ* and *Diatomaceæ* for example, are equally claimed by the botanist and the zoologist, so uncertain is it to which department of science they truly belong.

In the vascular class of plants, the structure is more complex, the organs are numerous and serve distinct purposes, and their elementary tissues have been divided into cells, fibres, and vessels: this subdivision has been proved by recent investigation to be illusory; vessels being merely modified or elongated cells; and fibres, elongated cells, the walls of which are thickened, or the entire cavity solidified by subsequent deposit on the internal surface of the cell wall.

The lowest types of animal life consist, like the analo-

gous vegetable forms, of simple cells ; but the progress of development in animals is much more rapid than in plants, producing a greater variety of external form and complexity of structure among groups which would otherwise hold a parallel position in the two kingdoms.

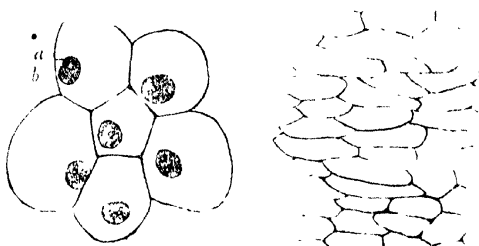
One great distinction between the elementary tissues of plants and animals, which should be always kept in view by the student is, that while in the plant the cell, however modified in form, still possesses all the characters of a cell ; in the animal it usually undergoes a development into tissues, in which the cellular form completely disappears, and the cellular origin of the tissue can only be discovered by studying it in its embryonic condition.

MEMBRANE.

It is now generally considered by vegetable physiologists that, with the addition of an intercellular mucus or *cambium*, all plants are made up of a membrane existing in the form of cells or utricles, having as an organic basis a tough insoluble material called *cellulose*. Membrane, therefore, is regarded as the sole element of plants. Some years since, fibre was also enumerated as an element, but more recent observation has shown that this is always subsequently deposited on the inner surface of membrane.

Membrane in its earliest stages is thin, transparent, and structureless, as shown in the outer membrane of the seed of a *Gourd*, Fig. 1. B, or at A, which represents cells obtained from the young flower-stem of a *Leek*. It is generally colourless, or has a greenish-white hue; in some cases, however, as in ferns, it is brown. The beautiful and varied colours of the corollæ of flowers do not depend upon the membrane com-

FIG. 1.



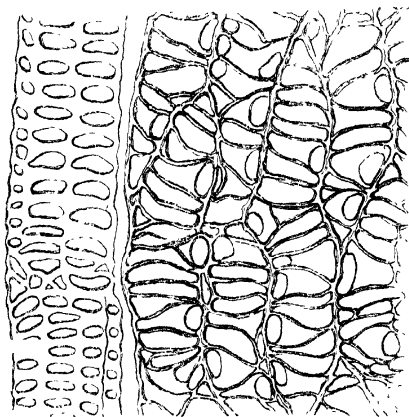
A, cells from the flower-stem of a *Leek*; a, cell-wall; b, nucleus. B, epidermis of the seed of the gourd, composed of cells.

posing the cells, but on the colouring matters which, chiefly in a fluid state, are contained in their interior. Membrane is also, at the stage at which I am describing it, entirely free from visible pores, although fluids readily pass through it by endosmose and exosmose; and, notwithstanding many cells and vessels, hereafter to be described, have their walls studded with dots and apparent foramina, the membrane is always present, but, in most instances, so excessively thin, that it

cannot be demonstrated until charred, or stained of a brown colour by the application of tincture of iodine.

Examples are not unfrequently met with in which cells or vessels having become old and dry, the membrane has disappeared, and holes have been left, and such is the case in the vessel from a *Balsam*, Fig. 2, A.

FIG. 2.



A, old cell from the *Balsam* exhibiting perforations. B, fibrous cells of *Sphagnum* with perforations.

True foramina, however, are found in the walls of newly developed cells in certain mosses of the genus *Sphagnum*. These cells (Fig. 2, B), are of a fusiform shape, have a spiral fibre developed within them, and exhibit a series of perforations on each side, which were first described by Mr. W. Valentine. I have satisfied

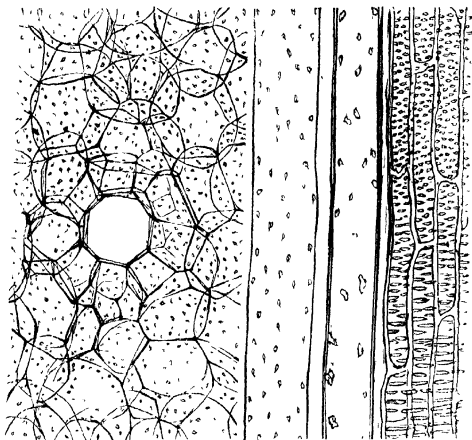
myself that they are true perforations by observing infusoria pass in and out of the cells in a young plant growing in water.

In process of growth, the thin membranous cell-walls become thickened by the deposition of new matter, either on their external or internal surface—more frequently the latter. The deposit is termed secondary, and, according to Schleiden, usually assumes a spiral direction. It is generally considered, that if the deposit take place before the cell has completed its growth, its form will be that of a spiral fibre or band, in consequence of the cell-wall elongating or growing more rapidly than the deposition takes place within the cell; but that, if the deposit take place after the complete development of the cell, it may then so happen that certain parts being left uncovered by the deposited material, pores, or pits having the appearance of pores, are produced. We have striking examples of cells containing spiral fibres, or bands, in many plants, especially the *Orchidaceæ*, as in the *Pleurothallis*, two cells from the leaf of which are shown in Fig. 4, E F, and in some elongated cells from the stem of a *Balsam* in Fig. 4, B.

The other form of deposit is more common, and is well exhibited in its earliest stage in the two specimens of the root of *Marchantia polymorpha*, in Fig. 3, B, C; or in A, which is a representation of the cells forming the pith of the *Elder*; the same fact is strikingly shown in the plant furnishing the Rice paper, and in the

Vine, as at Fig. 3, D; or it may be seen to still greater advantage in the elongated cells known as porous or

FIG. 3.



A, pitted or dotted tissue of the pith of the *Elder*. B C, pitted ducts from the root of *Marchantia polymorpha*. D, pitted cells of the *Vine* (*Vitis vinifera*).

dotted ducts, specimens of which are readily obtained from the *Alder*.

In all these examples there are no apertures in the membrane or cell-wall; but in some old cells from the stem of a *Balsam*, Fig. 2, A, the membrane has been destroyed, and holes are left. This destruction of the cell-membrane is particularly evident, both in the cells and vessels of many specimens of fossil wood, which no doubt had undergone some slight

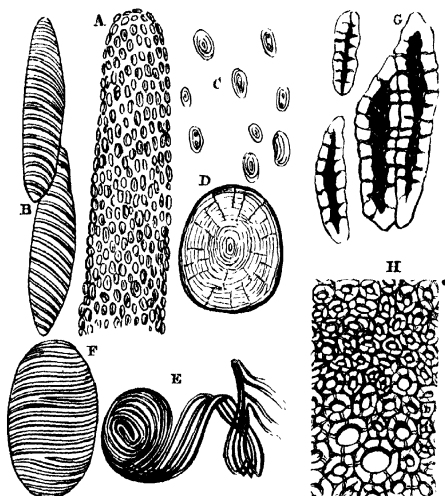
decomposition before being silicified. Two preparations are described in the Histological Catalogue of the Museum of the College of Surgeons, H 58-59, in both of which the membrane has been destroyed. In the one a series of oval holes, and in the other only an irregular hexagonal network, indicate the original porous type of the vessels.

Membrane may also be thickened by a deposit so dense as nearly to resemble bone. We have examples of this in the stones of the plum, peach, cherry, &c., and more especially in a nut known as vegetable ivory. This hard material called *sclerogen* by Turpin may occur in a homogeneous form, or in concentric strata, but the deposit being rarely if ever sufficient to fill the cell entirely, leaves a central cavity with radiating canals or pores, which, upon section, resembles one of the lacunæ of bone; but in these sclerous vegetable tissues the radiating canals never pass beyond the walls of their proper cells, and never anastomose with those of neighbouring cells. The thickening of the walls of cells is well shown in the vertical and horizontal sections of one of the scales of the cone of *Pinus Webbiana*, represented in Fig. 4, G H, in both of which the pores radiating from the central cavity, and proceeding as far as the cell-wall, are distinctly seen; in Fig. 4, D, is shown a large ligneous cell from the Snake-wood, in which the deposit has taken place in concentric strata.

The specimens already described are instances of

deposit on the internal surface of membrane; examples, however, are not wanting in which the deposit has

FIG. 4.



A, hair from the fornx of *Anchusa italica*. B, cells from the stem of a *Balsam*. C, tubercles from the hairs of *Anchusa*. D, ligneous cell of the *Snake-wood*. E F, cells from leaf of *Pleurothallis*. G H, vertical and horizontal sections of cells of a scale from the cone of *Pinus Webbiana*.

taken place on the external surface, but these are rare in comparison with those illustrating the former mode of deposition. In the hairs of the fornx of *Anchusa italica*, a portion of one of which is represented by Fig. 4, A; the outer surface of the thin violet-coloured membrane is studded with oval tubercles, some of which are shown in Fig. 4, C; these were first pointed out by Schleiden.

In a portion of cuticle taken from an *Aloe*, the tubercles are so large as to give the membrane a rough appearance even to the naked eye.

F I B R E.

Fibre, although at one time regarded as an element of vegetable tissues, is now generally looked upon as a secondary formation deposited within the walls of cells, or, in other words, on the internal surface of membrane. It is solid, sometimes transparent, and generally speaking of a greenish-white colour, though in some few plants, as in the elaters of *Jungermannia*, it is more or less red. Its direction, as shown in Figs. 5 and 6, is most frequently spiral, the spires running from right to left; in some plants, however, the direction is from left to right. According to Lindley, it is straight in the lining of the anther of *Campanula* and *Digitalis purpurea*. Fibre varies considerably in size; in some plants it exceeds $\frac{1}{1000}$ th of an inch in diameter, in others, it surpasses in delicacy the finest hair; it generally adheres very firmly to the sides of the cell-wall, especially in the young state, when the turns of the spiral are very close together, but as the cell elongates, the fibre sometimes keeps pace with it, and the turns are more widely separated. Two or more contiguous turns are very prone to "anastomose,

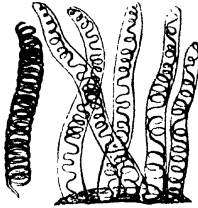
and it is in this way that all the peculiar markings found in cells are formed, such as the rings, dots, and reticulations hereafter to be described. When the spiral cells are fully developed, as shown in Fig. 4, E, the fibre will separate from the membrane of the cell-wall, and its elasticity is such, that it ever tends to unroll itself, and in old elongated cells or vessels, it frequently ruptures the membrane, and becomes more or less straight. In this way the fibre may be obtained in an isolated condition.

The bulbs of many of the lily tribe, and one species of squill from the Mediterranean, contain such immense numbers of spiral vessels, that the entire series of laminae of which they consist, appear to be composed of spiral fibres. These fibres are obtained in such abundance from some plants, that they are collected, bound into bundles, and used as a kind of slow match for lighting pipes and cigars. The elasticity of spiral fibre is very beautifully shown on the testa of the seeds of many plants, as the *Collomia grandiflora*, *Salvia pratensis*, &c. When a minute portion of the testa is moistened with water, cells that were so closely adherent as not to be distinguished become soft, the spiral fibre released, as it were, from its close captivity, uncoils itself and pushes the cell-wall before it, and what was at first a brown shapeless object, becomes a mass of beautiful spiral cells ; a few of these cells from the *Collomia* are represented in Fig. 5.

Fibre, like membrane, is frequently increased in

thickness by successive deposits, so that the spiral thread becomes a flattened band or even a ring, like a

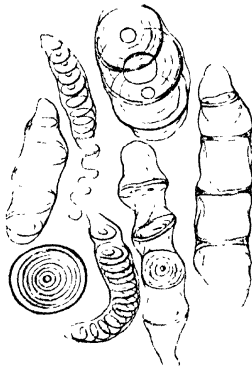
FIG. 5.



Cells from the testa of the seed of *Collomia grandiflora*.

quoit, as in Fig. 6, which represents cells of *Opuntia vulgaris*, with fibres in various stages of development.

FIG. 6.



Cells with thickened fibres from *Opuntia vulgaris*

Some of these cells exhibit thickened fibres, others have the fibre converted into a flattened band; whilst in a few may be seen the ring-shaped bodies affording evidence of concentric deposit.

LECTURE II.

CELLS.

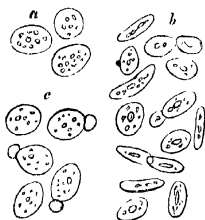
IN the first Lecture it was stated that the most simple plants are composed of cells or utricles, and that all others, however complicated in structure, are made up of a series of such cells, variously modified by pressure, and arranged according to the conditions under which they are developed and the functions they have to perform. Within the transparent membrane of which the young cell alone consists, there is in the growing cell a thin delicate lining, termed the primordial utricle of Mohl; within this is a nucleus or cytoblast, and this again contains smaller cells or nucleoli. The typical form of the cell is either spherical or oval; but by pressure in growth, cells assume almost every variety of shape, and their walls become thickened either uniformly or partially. In the most lowly organized plants among the *Algæ* and *Fungi*, the cells maintain their original form throughout life; but in the majority of instances,

as has been already stated, they undergo much alteration in shape. The following are the chief forms which have been specially named by botanists; the oblong, lobed, square, prismatic, cylindrical, fusiform, muriform, sinuous, stellate, filamentous, &c.

In pulpy fruits, such as the ripe strawberry, the cells may be readily separated from each other, and obtained in an isolated condition; many of them, in the lemon, will be found to be upwards of half an inch in length; in the shaddock they are much larger, but in most fruits and other parts of plants, the agency of maceration, or boiling water, must be resorted to for their separation.

One of the most striking, and at the same time most interesting examples of the typical form of cell, is the *Torula cerevisiæ*, or yeast-plant, shown in Fig. 7,

FIG. 7.



a, three cells of *Torula cerevisiæ*; *b*, cells of *Torula diabetica*; *c*, cells of *Torula cerevisiæ* developing new cells.

a. This, like the *Torula diabetica* so constantly present during the fermentation of diabetic urine, is the earliest condition of a fungus, very nearly allied to the common *Mucor* or mouldiness. When yeast is examined by a high power of the microscope, it is seen to consist of myriads of minute simple ovoid cells. Shortly after,

being placed in contact with a solution of sugar or infusion of malt, these cells develop smaller cells from one or two points of their external surface, Fig. 7, *c*, which,

when full grown, give the plant the appearance of a necklace. The further development, which cannot be fully described here, proceeds to the formation of jointed tubes and filaments, when these rise to the surface, and are exposed to the air, the complete development into the *Penicillium glaucum* occurs. Another species of *Torula* is found in the urine of diabetic patients as soon as fermentation commences; hence it has been named *T. diabetica*. For the sake of comparison with *T. cerevisiæ*, a few of these cells are represented in Fig. 7, *b*; they are much smaller, and more oval in shape, and are beginning to be arranged in a linear series. This is always found to be the case both in new beer and in urine, if kept for a few days.

There is a disease of the stomach characterised by a very constant train of symptoms: dilatation with flatulent distension, a burning or scalding sensation referred to the epigastrium and upwards in the course of the œsophagus, and the frequent vomiting of a clear fluid, with or without the admixture of a small quantity of brown, frothy matter, like yeast. The patient complains that the vomited fluid is excessively acid to the taste, and its acidity is readily demonstrated by litmus-paper. Within an hour or two after ejection, it begins to ferment as distinctly and rapidly as new beer wort, and a head is formed which cannot be distinguished, in appearance or odour, from yeast. When placed under the microscope, it is seen to be mainly composed of minute cubical masses of a greenish

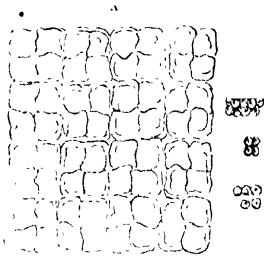
colour, intersected by crucial lines, and these are again divided and subdivided by similar markings. These bodies were first noticed by Professor John Goodsir, and by him described in the "Edinburgh Medical and Surgical Journal," in 1842, under the name of "*Sarcina ventriculi*," and he conjectured that they were of the nature of parasitic vegetables of low organization. They much resemble the infusorial animalcules depicted by Ehrenberg, under the name of *Gonium pectorale*, so named from an ornament worn on the breast of the Jewish high-priest. Mr. Busk has since noticed them, in the "Microscopical Journal," as occurring in three cases under his care in the 'Dreadnought' hospital-ship, one being a patient suffering from rupture of the diaphragm; and my late brother met with and described a case at one of the meetings of the Microscopical Society; but in this instance they evidently belonged to a distinct species of the same genus.

The specimen in my possession was obtained by Mr. Monckton from a patient in King's College Hospital, under the care of Dr. Budd, from whom we may expect an elucidation of the most effective plan of treatment of this serious disease. I am inclined to think that the administration of remedies best calculated to destroy vegetable life, or fermentation, will prove most effectual in removing this affection; although, hitherto, the disease has generally been found in cases which have terminated fatally.

Two masses of the *Sarcina* are represented in Fig. 8,

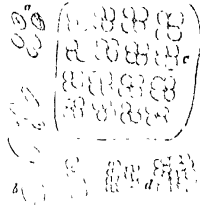
A, and B, the former magnified eight hundred diameters,

FIG. 8.



A, cubical masses of *Sarcina* magnified 800 diameters. n, cubical masses of *Sarcina* magnified 250 diameters.

FIG. 9.



a, *Torula* occurring with the *Sarcina*; bb, cells of *Torula diabetica* and *cerisea*; cd, cells of the *Gonium pectorale*.

is shown at A. In the same fluid (Fig. 9, a) we have a great number of minute oval cells, resembling the *Torula* of the *Yeast-plant*, which are probably the spores or sporangia of the *Sarcina*. The *Gonium pectorale* is represented in Fig. 9, cd, for comparison with the *Sarcina*. The colour of the *Gonium* is always a bright green, and in the fresh state individuals may be seen moving rapidly across the field of the microscope. As they form the nearest approach to the *Sarcina*, a representation has been given. In the vomited matters many other substances are detected under the microscope, such as fat, starch, muscular fibre, &c.; but with these we have nothing to do at present.

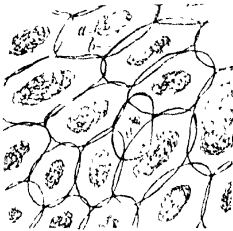
The probability of the development of the *Sarcina ventriculi* from the minute cells, observed in the vomited

fluid, leads me to repeat the remark that the latter bears a strong analogy to what has been called the *T. diabetica*, represented in Fig. 7, *b*, and Fig. 9, *b*, in form and in capability of exciting fermentation. The *T. diabetica* and *T. cerevisiæ*, are neither of them perfect plants, but an intermediate and subaquatic stage of the development of fungi, belonging to the order *Mucorinæ*. Turpin has demonstrated that the *Yeast-plant*, misnamed *T. cerevisiæ*, is an early condition of the *Penicillium glaucum*; and my friend, Dr. P. B. Ayres, has informed me that he has traced the development of the *T. diabetica* to a species of *Mucor*, probably *Mucor ramosus*. Each oval cell or spore, first develops one or two smaller cells, by germination on opposite points of its surface, these increase in size, and each again produces other cells, so as to form a moniliform string of cells, or *torulæ*. The next stage of development is into jointed confervoid, tubes more or less irregular in figure, and these increasing in number form cloud-like masses, which ultimately rise to the surface of the fluid by the aid of bubbles of carbonic acid, and the upper surface being exposed to the air partially dries, and in a short time the vesical fructification of the fungus is produced. The genus *Torula* ought clearly to be abolished, its so-called species being simply stages of development of a more perfect plant.

The ripe *Strawberry* affords an example of larger cells of an oval shape (Fig. 10) containing a brownish nucleus, *a, b*; and in those from the young flowering

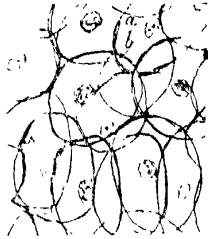
stem of the *Leek*, represented by Fig. 11, the nucleus *a*, and nucleolus *b*, are easily recognized.

FIG. 10.



Cells from a ripe *Strawberry*: *a* *b*,
brown central nucleus.

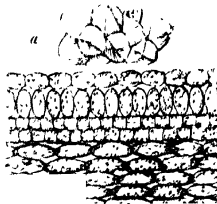
FIG. 11.



Cells of a *Leek*: *a*, nucleus; *b*, nu-
cleolus.

It would, I fear, occupy too much time to exhibit to you each of the varieties of cells before enumerated; but, in this section of the leaf of a *Balsam* (Fig. 12), and

FIG. 12.

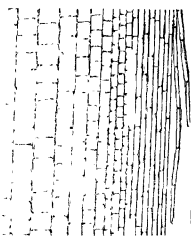


Vertical section of the leaf of a *Balsam*; *a*, cells from the
stem of the same plant.

in the mass *a*, from the stem of the same plant, most of the forms may be distinguished, more especially the

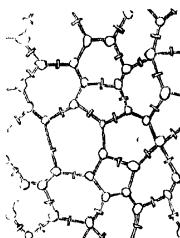
square, the oblong, and the lobed; in the section of the rind of a *Gourd*, represented by Fig. 13, you will notice, that cells more or less cubical may become prismatic, or even be so much compressed towards one edge, as to assume the appearance of fibres. There are, however, some of the varieties which demand a more

FIG. 13.



Vertical section of the rind of a
Gourd.

FIG. 14.

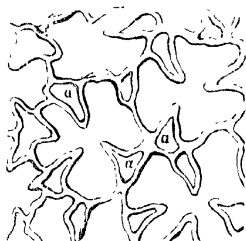


Stellate cells from the young petiole
of *Sparganium ramosum*.

particular description; one of the most remarkable of these is the stellate cell, which is found in the pith of some rushes, the petiole of the sweet Burr-reed (*Sparganium ramosum*), and in the stems of many aquatic plants. In the young petiole of the *Sparganium* there are strata of hexagonal cells which form septa; these, as shown in Fig. 14, have around their margins certain notches, which, with those in adjacent cells, form triangular apertures, known to botanists as *lacunæ*; in process of growth these notches become deeper and deeper, the lacunæ, *aa*, enlarging at the expense of the area of the cell-wall, which gradually

assumes more and more the appearance of a star, as shown in Fig. 15. In the *Rush* we have a very beautiful example of this form of tissue, the cell being

FIG. 15.



Stellate cells from fully developed petiole of *Sparganium ramosum*; *aaa*, lacunae.

FIG. 16.



Stellate cells from the stem of a *Rush*; *aaa*, black lines indicating the cell-walls.

reduced to a six-rayed star, as shown in Fig. 16, but the remains of the cell-wall, indicated by the black lines, *aa*, are always present. By this alteration in the shape of the cells, the stem becomes lighter, and in this way the large receptacles for air, common in most water plants, are formed.

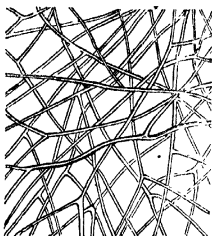
FIG. 17.



Elongated cells of the *Mushroom*.

Very striking specimens of the filamentous form of tissue are obtained from many of the fungi, as the common edible *Mushroom*, in which the cells are of a long oval figure, and joined end to end, as shown in Fig. 17; but in the *Boletus igniarius*

FIG. 18.



Elongated cells of *Boletus ignarius*.

they are so greatly compressed and elongated as to assume the appearance of fibres; many of them, as shown in Fig. 18, are seen to bifurcate; but a transverse line, indicating the cell-wall, is occasionally visible.

Another variety of cell arrangement is known as the muriform, from its resemblance to that of bricks in a wall; it forms the medullary rays of most woods, and gives to them the peculiar appearance known as the silver grain; such cells are readily seen in the *Coniferæ*.

Other forms, especially the sinuous, occur in the cuticle of most plants; the cylindrical, however, is best seen in the *Characeæ*.

From the form and structure of cells, we proceed to consider the nature of their contents; these are colouring matter, starch, oil, raphides, silica, &c. I have already stated, that the beautiful variety of colours seen in the corollæ of flowers is dependent, not upon the membrane composing the cells, but upon colouring matters, usually of a fluid nature, contained within them. The cells of the cuticle of the common garden *Rhubarb* afford an excellent illustration of this fact; some of them filled with a red coloured fluid occurring singly among others destitute of colouring matter. In the corolla of a *Pelargonium*, most of the cells are full

of crimson fluid, which imparts to this favourite flower its rich hue. In the case of the ferns before alluded to, the brown colour depends on that of the cell-wall, and not on its contents. In old cells of *Palms* and certain *Coniferæ*, resinuous matter of rich colour is often met with; this, however, is solid, and is very remarkable in the palm yielding the substance called dragon's blood. The green colour, so universally present in plants, is due to a more or less solid material, contained in cells and termed chlorophylle, or green vegetable wax; it consists of minute spherical or oval particles, but as these have certain properties in common with starch, they will be more particularly described with that substance.

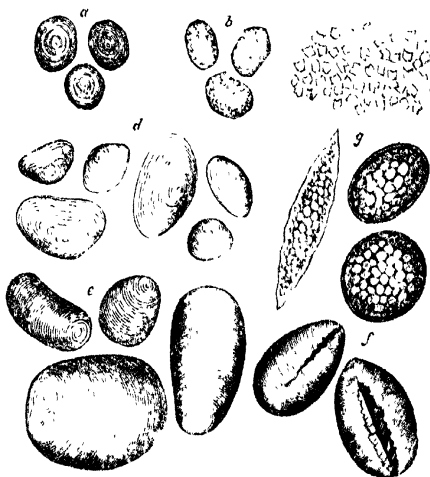
LECTURE III.

STARCH.

Starch, which performs a similar office in the economy of plants to that of fat in animals, is a most important ingredient in the aliment of the whole human race, two-thirds of mankind subsisting almost exclusively upon it; its existence was known to the ancients. Leeuwenhoek first examined it microscopically in wheat and beans, and has given tolerably accurate representations of the granules in the second volume of his works. Starch is found in the cells of plants in the form of granules, as in Fig. 19, *g*, from the *Rhubarb*, the cells of which have been separated by maceration; also in a section of a *Potato*. It is usually obtained by rupturing the cell-walls and washing out their contents with cold water; when dry it is hard, and if rubbed between the fingers, a peculiar crackling sound is produced. Starch is insoluble in cold water, alcohol, ether, volatile and fixed oils; boiling water, however, changes its properties, causing

rupture of the granules and the liberation of starch, gum or dextrine. For this reason the starch granules

FIG. 19.



a, Granules of *Wheat-starch*; *b*, *Sago-meal*; *c*, *Rice-starch*; *d*, *Potato-starch*; *e*, *Tous les mois*; *f*, bursting of starch grains on the application of heat; *g*, isolated cells of the *Rhubarb* containing starch granules.

almost wholly disappear in boiled potatoes. When examined microscopically, starch is found to consist of more or less oval granules of various sizes, having definite and peculiar characters in different plants; thus in the *Tous les mois*, Fig. 19, *e*, they are of very large size; in the *Potato*, Fig. 19, *d*, they are much smaller; and in the *Rice*, Fig. 19, *c*, are so very minute as to require a power of two hundred and fifty diameters to discover them.

Each granule has at one extremity a circular spot, termed the *hilum*, around which are a large number of curved lines, passing at first in circles concentrically, and subsequently in curves around the *hilum*, these markings are not, as has been imagined, the result of consecutive deposits, nor indications of increments of growth of the granule itself; they are confined to the cell-wall, and are most probably mere tranverse puckeringings or rugæ in the membrane, of which, together with its amylaceous contents, the starch granule consists. If sulphuric acid, and heat be gradually applied to starch, the granules swell to three or four times their ordinary size, and the distended cell-walls lose all trace of the markings which previously existed. When starch is boiled in water, the cell-membrane swells and bursts; the first stage of which is shown in Fig. 19, *f*, and the amylaceous matter becomes intimately mixed or dissolved in the fluid.

The presence of starch, however minute in quantity, can be immediately recognized by the addition of free iodine, which forms with it a compound of a beautiful blue colour, the iodide of starch—this test was discovered by Jurine. A little tincture of iodine added to the grains of starch in a section of the potato will make each granule blue, but will not so colour the vegetable cells in which these granules are stored up. If a small quantity of starch be boiled and poured into a vessel of cold water, the addition of a few drops of tincture of iodine will give the water a rich blue colour; if a

little of this water be examined under the microscope, the colour will be seen only in the remains of the granule-membrane; and if the water be allowed to stand, all the colouring matter will fall to the bottom of the vessel as a precipitate, showing that all parts of the starch grain are of greater specific gravity than water.

I have stated that the starch grains have definite and peculiar characters in different plants; and as starch, under certain names, such as *Tous les mois*, tapioca, sago, arrow-root, &c., is largely used by invalids and children, it becomes of importance for us, as medical men, to be able to detect frauds which are frequently practised in these articles. In Fig. 19, *a, b, c, d, e*, &c., you have representations of the principal varieties of starch, all of which are drawn to a fixed scale; they, therefore, exhibit their peculiar form and proportionate size; and it will be readily seen that by means of the microscope, any mixture of two or more of them, or of other varieties with them could be easily detected, as was strikingly exemplified, some years since, in a case which our distinguished chemist, Dr. Ure, was employed to investigate. This was an attempt to import the starch of the Cassava, which bears a duty, as arrow-root, upon which there is no duty; thereby an attempt was made to defraud the revenue to a considerable amount. The difference between the two starches was not sufficiently obvious to the naked eye; but by means of the microscope, and a knowledge

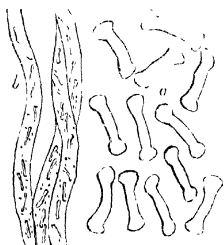
of the nature of the grains, the Doctor was enabled to detect the imposition.

Could it be proved that a direct relation exists between the size of the starch granules and their nutritive quality, we should, of course, possess a ready method of determining such quality in any given specimen; and, on this principle, *Tous les mois* would be considered as much more nutritious than the potato, and the potato than the rice starch.

Starch possesses the property of polarizing light; each grain shows a black cross surrounded by coloured rings, changing to a white cross, with the complimentary colours of lower intensity when the analysing prism is revolved.

In the euphorbiaceous plants, the starch granules

FIG. 20.



a, club-shaped starch grains of *Euphorbia splendens*; *b*, three of the laticiferous vessels with starch grains *in situ*.

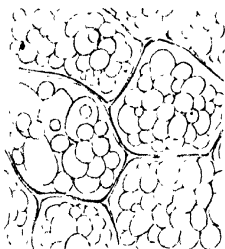
have a peculiar form and situation; they are found in the interior of the laticiferous vessels, floating in the latex or milky juice, Fig. 20 *b*, and their shape is that of an elongated dumb-bell, or two-headed club, as shown at *a*. They are easily exhibited by wounding the plant, and placing a drop of the milky juice under the microscope, and

these singular granules are proved to be really starch, by the addition of tincture of iodine, which gives them a deep blue tinge.

Before leaving the subject of starch, allusion may be

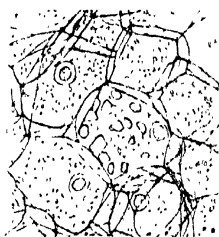
made to the recently prevalent and destructive epidemic among the *Potatoes*, which I believe to have been a disease of the tuber, not of the haulm or leaves. Examined in an early stage, such *Potatoes* are found to be composed of cells of the usual size, but they contain little or no starch; and hence it may be inferred, that the natural nutriment of the plant being deficient, the haulm dies, the cells of the tuber soon turn black and decompose, and *fungi* are developed as on most other decaying vegetable substances. A portion of healthy *Potato*, shown in Fig. 21, consists of a series of more

FIG. 21.



Portion of healthy *Potato* with starch grains *in situ*.

FIG. 22.



Portion of diseased *Potato* showing absence of starch.

or less hexagonal cells, full of granules of starch of different sizes; the granules, when highly magnified, exhibiting the peculiar markings represented in Fig. 19, *d*.

In the diseased tuber, illustrated by Fig. 22, it will be noticed that the starch-grains are absent from nearly all the cells, their place being occupied by numerous minute

granules of a brown colour. In many of the cells, a large circular nucleus or cytoblast is present. In other

FIG. 23.



Portion of diseased *Potato* with fungus.

parts of the same *Potato*, in which the disease is further advanced, not only is the starch absent, but a moniliform fungus, as shown in Fig. 23, occupies many of the cells, and threads its way between others. In this section, the parts containing numerous brown granules exhibit the greatest number of fungi.

The next, and one of the most common of all the cell-contents, is known as *chlorophyll*. It has been before alluded to as the cause of the green colour of plants, and exists in the leaves and young stems of almost all the flowering plants, when not deprived of the action of light.

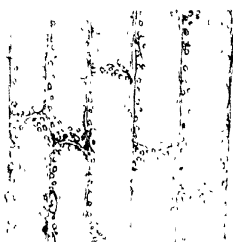
Chlorophyll is soluble in alcohol and ether, but is not acted on by water. It forms a thin coating to the granules found in the interior of cells, some of which are said to be composed of mucilage, and others of starch, as is proved by their being rendered blue by iodine. That most remarkable phenomenon, the circulation of the contents of vegetable cells, or, as it is technically termed, *cyclosis*, may be examined at the same time as the *chlorophyll* granules; the specimens selected for this purpose being either transparent water-

plants, such as the various species of *Chara*, *Nitella*, and *Vallisneria*, or the hairs of the *Groundsel* and *Tradescantia*.

The stem of the *Nitella* consists of cylindrical cells, in most of which a movement of granules may be observed; they pass up on one side of the cell and down on

the other, but never escape into adjoining cells. The circulation may, however, be more plainly seen in the *Vallisneria*; a thin layer of one of the flattened leaves of this plant will exhibit a series of oblong cells, as shown in Fig. 24, in each of which an active circulatory movement

FIG. 24.



Portion of leaf of *Vallisneria
spiralis*

of the green granules may be noticed; among the granules so moving may be discerned one larger and more transparent than the rest—the nucleus or cytoplasm of the cell, having a nucleolus within it.

I shall now proceed to describe very briefly some of the other contents of cells, such as milky-juices, oils, resins, &c., all of which are important to mankind, some being universally employed as food, others extensively used in the arts.

Milky-juices are true secretions found in many plants, and contained in distinct vessels called milk or laticiferous ducts, formed by the union of elongated cells, which,

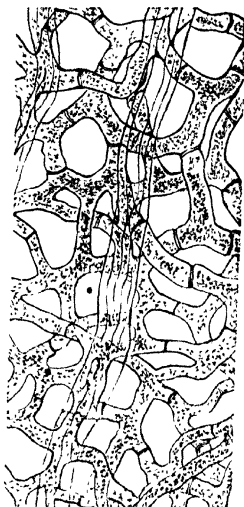
unlike other vessels in plants, are commonly subdivided or branched. The *Dandelion* contains a large quantity of this juice; Indian-rubber, or caoutchouc, is the concrete milky juice of the *Ficus elastica*, and many species of this genus secrete a similar milky fluid.

Gutta-percha resembles caoutchouc in its origin, but the milky-juice that yields it, contains a more considerable amount of starch. As this material is now coming into such general use, it may not be out of place to give you the derivation of its name, as I have never yet seen it correctly stated in books. On referring to a map of Asia, you may observe that the Island of Sumatra presents a ragged outline. The Malay name for this island is Pulo-Percha, "pulo" signifying "island," and "percha," "ragged." "Gutta" is the Malay term for gum, hence this substance received the name of "gutta pulo percha," or gum from the ragged island. It has, however, become the custom of late years to omit the word "pulo," as in the case of Penang, which was formerly called Pulo Penang, and thus this substance has received the name of gutta-percha. The above information was communicated to me by a friend residing in Penang.

Our countryman, Nehemiah Grew, was not only aware of the presence of milks in plants, but, in his anatomy, speaks of many which "bleed a lymph." He even gives drawings of the vessels which contain it, but does not appear to have been cognizant of their

branched character. These vessels, which have been particularly investigated by Schultz, were supposed by

FIG. 25.



Milk-vessels from the stipule of
Ficus elastica.

him to exhibit a circulation; but, it has been found, by subsequent examination, that the circulatory movement is due to the contraction of the vessels themselves, which have always a tendency to expel their contents when torn or divided.

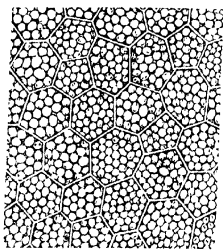
In the stipules of *Ficus elastica*, the Indian-rubber plant, a layer of branching laticiferous vessels exists, of which Fig. 25 is a drawing; these vessels contain granular matter. In another specimen taken from the *Dandelion*, the milk-vessels are

readily recognised by their frequent bifurcations, and by their contents having been changed to a brown colour by the liquid used to preserve them.

Fixed Oils and other matters are found as contents of cells; they are highly nutritious, and are chiefly met with in the seeds of plants, in which they serve the purpose of nourishing the embryo, until the development of the radicle and plumule has provided organs capable of deriving sustenance from other sources. In

the *Cocoa-nut*, the cells contain a concrete oil, which when extracted by pressure, is an article of considerable commercial importance, being much employed for combustion in lamps, and for the manufacture of candles. In the process of germination the oil is absorbed by the embryo, so that the albumen of the seed is gradually

FIG. 26.



Portion of a *Cocoa-nut* with cells full of globules of concrete oil.

diminished and shrivels, a fact well exhibited by a *Cocoa-nut* after germination. It is somewhat difficult to demonstrate the oils, *in situ*, in the cellular tissue, since the section almost necessarily allows the escape of the oil; but, in some parts of the *Cocoa-nut* this is concrete, and we have a better chance of displaying it in the cells.

Some of these are represented in Fig. 26. The oily matter consists of minute spherical globules, which are so closely packed as to render the section partially opaque.

The presence of oily matters in vegetable cells was known, and even depicted by L^ec^uw^en^ho^ek, in the second volume of his works.

Palm Oil resembles fat rather than oil, and is used by the natives of the western coast of Africa as a substitute for butter. It is now extensively employed in the manufacture of candles, and likewise on the railroads, for greasing the wheels of the carriages, sulphur

being added to prevent it from melting too rapidly. This oil is contained in the cotyledons of the seeds, from which it may be extracted by heat and pressure; when sulphuric acid is added to it, copious fumes of gas are evolved, and the oil turns black, it is then subjected to distillation, stearic acid comes over, and the residue is a material like black sealing-wax. This is the principle of Price's patent process. Human fat is capable of being separated by pressure into a solid and fluid portion; the solid principle is termed margaric acid, the liquid glycerine. In animals as well as in vegetables, the oil or fat is produced by and stored up in the interior of closed cells.

Castor, croton, linseed, rape, poppy, and numerous other oils, are examples of these vegetable fats. An oil expressed from the seeds of a species of *Jatropha*, burns exceedingly well in lamps, and gives a steady white light. It is manufactured in Bristol by Messrs. Visger and Miller, and sells at four shillings per gallon; but it is of a poisonous nature, and cannot be even tasted with impunity. A bag of the nuts having accidentally burst on the quay at Bristol, many children picked them up and eat them, and in a short time numbers of the children were taken into the infirmary with symptoms of irritant poisoning. Some of them suffered severely, others less so; but I believe no fatal result ensued in any case. A gentleman, well skilled in the properties of oils, imprudently dipped his finger into a specimen of this oil, and carried it to his mouth, in order

to judge of its quality ; he was rendered uncomfortably ill for two or three days.

Nor is it in the animal and vegetable kingdoms alone that we meet with oil, since it has also been obtained from the mineral kingdom. Mineral oil derived from bitumen is of a dark colour, somewhat resembling brandy, and burns exceedingly well in lamps. The paraffine extracted from peat by destructive distillation, by Mr. Owen's process, is employed for making candles. Peat appears to be capable of conversion into a great variety of useful products, many of which are at this time gaining much attention from practical men.

Volatile Oils are also secreted in cells, which, from their peculiarities of shape and situation, have received the names of vesicles, vittæ, glands, &c. They occur on the surface or in the parenchyma of leaves, and in the pericarp of fruits. They are not nutritious, are soluble in alcohol, but not in water. The volatile oil of the rind of the lemon and orange, is contained in such vesicles, and connoisseurs in punch are well aware, that by rubbing a lump of sugar over the outer surface of the lemon, the sugar absorbs the essential oil, and thus imparts a fine flavour to the liquor ; the sugar being rough acts the part of a grater, rupturing the cells in which the oil is contained, and allowing it to escape.

Many of these essential oils, when evaporated, yield a resinous substance. The resin may be sometimes seen on the surface of plants yielding a perfume. There is a striking example of this in the seed of the common

lavender, which, when examined as an opaque object, presents rows of small globular bodies of highly refractive powers situated in the furrows of the seed. If the seed be dipped in alcohol, the resinous matter will be immediately dissolved.

Camphor is a substance nearly allied to the volatile oils, differing from them in being solid at ordinary temperatures. It may be found in larger or smaller masses, in the cracks and fissures of the wood of *Laurus camphora*, as in a specimen belonging to John Hunter, which is still preserved in the Museum.

Gum, is another substance, formed originally in cells, but subsequently separated from the plant as an excretion. The purest form of gum is that known as the gum arabic, produced by the *Acacia vera*, which is very soluble in water, forming a transparent solution; the gum tragacanth, from the *Astragalus tragacantha*, cannot be said to dissolve, but forms a soft opaque mucilage, resembling paste.

Wax and *Tallow* are also found in plants, the former in large quantities on the surface of the *Wax-palm*, *Ceroxylon andicola*, whilst the latter occurs in the seeds of *Pentadesma* and *Bassia*, of Sierra Leone, both having the specific name of *Butyracea*. The bloom of the plum and the grape are also examples of wax.

Resins abound in some plants, especially in the coniferous species; they are not unfrequently contained in large reservoirs, termed turpentine vessels. When that from the common *Pine* is distilled, oil of turpentine

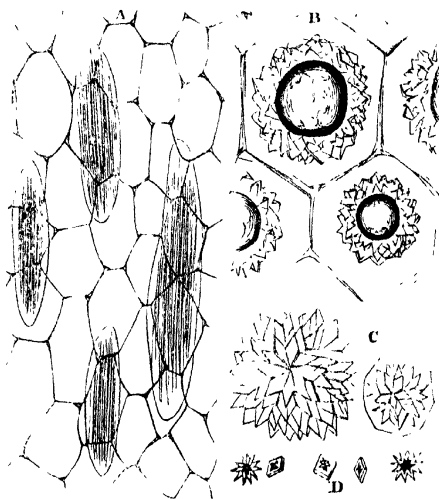
comes over, and the residue is known as the "black" or "fiddler's resin." If, however, water be added prior to the distillation, the residue is the white resin of commerce.

Canada balsam now so largely used for mounting microscopic objects, is an example of a liquid resin.

RAPHIDES.—Besides the various contents of cells which have already occupied our attention, there are certain mineral substances commonly found in them in the form of crystals. These were first noticed by Malpighi, in the *Opuntia*; and were subsequently described by Jurine and Raspail. They occur principally in two forms, either in stellate masses, as shown in Fig. 27, B, c, or in bundles of sharp-pointed crystals, very much resembling needles, as in Fig 27, A. It is these last which have obtained for themselves and their fellows the general name of raphides, from the Greek *ῥαψίς*, a needle. They are also not unfrequently found as single crystals, in the form of octohedra, rectangular, and oblique prisms. According to Raspail, the needle-shaped, or acicular, are composed of phosphate, and the stellate of oxalate of lime. There are others having lime as a base combined with tartaric, malic, or citric acid. These are easily destroyed by acetic acid, and are also very soluble in many of the fluids employed in the conservation of objects. Some of them are as large as $\frac{1}{40}$ th of an inch, others as small as $\frac{1}{1000}$ th; they occur in all parts of the plant, in the stem, bark, leaves, stipules, sepals, petals, fruit, root, spiral vessels, and even in the pollen. They are always situated in cells, and not as

has been stated by Raspail and others, in the inter-cellular passages. Some of the containing cells become much elongated, but still the cell wall can readily be traced.

FIG. 27.

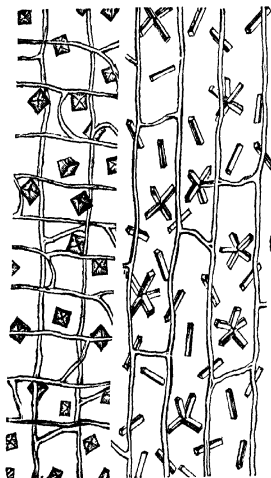


A, portion of outer layer of bulb of *Scilla maritima*, having acicular raphides in some of its cells. B, conglomerate raphides in the cuticle of a *Cactus*. C, stellate raphides in root of *Rhubarb*. D, raphides from the bark of the *Lime-tree*.

In a thin section of the leaf of an aloe, the *Aloe verrucosa*, small silky filaments may be discerned by the naked eye, which, when magnified, are found to be bundles of acicular raphides. In the bulb of the medicinal squill, *Scilla maritima* (Fig. 27, A), certain large

cells are detected immediately beneath the cuticular layer, filled with bundles of acicular crystals.

FIG. 28.



A, octohedral crystals of oxalate of lime in the cells of an *Onion*. B, prismatic crystals of oxalate of lime in the cells of another part of the same *Onion*.

In the cuticle of the *Onion*, every cell is occupied by an octohedral or prismatic crystal of oxalate of lime. In one specimen, Fig. 28, A, the octohedral form predominates; whereas, in others, Fig. 28, B, the crystals are chiefly prismatic, and are beginning to form stellate groups.

All who are in the habit of examining the deposits from urine must be familiar with the appearance of the crystals of oxalate of lime, and will readily recognize their close resemblance to these in the cells

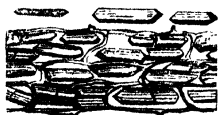
of the *Onion*. I have also met with them in the urine, contained in the interior of cells, so that, both in the animal and vegetable kingdoms, we have crystals of oxalate of lime as a product of cell secretion.

Raphides of oxalate of lime are found in very great abundance in the medicinal *Rhubarb*, as shown in Fig. 27, c; the best specimens from Turkey, containing as much as thirty-five per cent. of them, those from the

East Indies twenty-five per cent., and the English or that sold in the streets by men dressed as Turks, ten per cent. Buyers of this drug usually judge of its quality by its grittiness, that is, by the quantity of raphides it contains, and this is the more curious, as the crystalline matter cannot from its nature, contribute to the activity of the drug, since the tincture which contains no raphides, is as efficacious as the powder. Certain plants, of the *Cactus* tribe, seem to be almost entirely made up of raphides; in some instances every cell of the cuticle, as shown in Fig. 27, B, contains a stellate mass of crystals; while in others, the whole interior is full of them, rendering the plant so exceedingly brittle, that the least touch will occasion a fracture. On this account, some specimens of *Cactus senilis*, said to be one thousand years old, which were a few years since sent to Kew Gardens from South America, were obliged to be packed in cotton, with all the care of the most delicate jewellery, to preserve them during the transport. Raphides of peculiar figure are common in the bark of many trees.

In the hiccory, *Carya alba*, masses of flattened prisms,

FIG. 29.



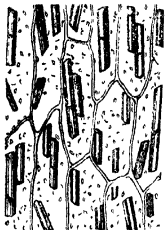
Prismatic raphides in the bark of the *Lime-tree*.

having both extremities pointed, may be observed; similar crystals are present in the bark of the *Lime-tree*, and in Fig. 29 they are represented *in situ*; they occur in rows, their pointed extremities nearly touching each

other, their principal situation being in the cellular tis-

sue, in contact with the medullary rays. Other forms

FIG. 30.



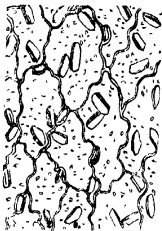
Prismatic raphides in cells of the pith of *Elæagnus angustifolia*.

FIG. 31.



Raphides in the bark of the *Apple-tree*.

FIG. 32.



Raphides in the testa of a seed of the *Elm*.

of crystals, as the rhombohedron, and a small stellate form, shown in Fig. 27, D, are also found in the bark of the lime. In a vertical section of the stem of *Elæagnus*, represented in Fig. 30, numerous prismatic raphides of large size are visible in the pith. Raphides are also found in the bark of the *Apple-tree*, as shown in Fig. 31, and in the testa of the seeds of the *Elm*, as shown in Fig. 32; each cell contains two or more very minute crystals.

It is not at present known what office raphides perform in the economy of the plant. Some have gone so far as to state that they are deposits to be applied towards the mineral part, or skeleton of the plant, but the fact of their being insoluble in vegetable acids would prove this view of their use to be erroneous. The more rational supposition is, that they are accidental deposits, formed by the action of vegetable acids upon lime or other bases, derived by the

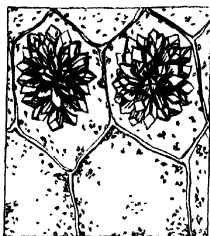
plant from the soil. Many of the larger kinds of raphides, as those from the *Cactus*, Fig. 27, B, do not consist entirely of earthy material, if they be acted on by an acid just strong enough to dissolve the lime, it will be found that an organic basis is left behind retaining, to a certain extent, the shape of the mass of crystals. Some of the masses even exhibit a laminated centre with crystals on their exterior, and when mounted in *Canada balsam*, they very much resemble small calculi, leading one to suppose that this was their true nature. They may, however, be formed artificially, and my late brother succeeded in doing so in the following manner: If oxalic or phosphoric acid be added to lime-water, the precipitate will be pulverulent and opaque. If, however, a vessel containing oxalate of ammonia in solution be connected by means of a few filaments of cotton, with another vessel containing lime-water; crystals will be formed at the end of the fibres in contact with the lime-water. This led him to attempt to form them in the interior of cells. He selected for the purpose a portion of rice-paper; this substance was placed in lime-water under an air-pump, in order to fill the cells with the fluid. The paper was then dried, and the process again and again repeated, until many of the cells were charged with lime-water. Portions of the paper were then placed in weak solutions of oxalic and phosphoric acid, and at the end of three days, crystals were found in the cells in both instances, those in the oxalic acid being

of the stellate form, while those in the phosphoric acid were rhombohedral. No acicular crystals, however,

were formed although the process was continued for ten days.

One of these pieces of *Rice-paper* exhibits very clearly a stellate mass of crystals in some of the cells. Each of these, as shown in Fig. 33, precisely resembles the raphides found in

FIG. 33.



Portion of *Rice-paper*, in which are two masses of raphides produced artificially.

Rhubarb.

Raphides are sometimes found in the fossil state. In a section of a fossil palm, from Saugur, in the Deccan, a stellate mass, evidently of a crystalline nature, occupies nearly the whole of the interior of some of the larger cells.

LECTURE IV.

SILICA.

BESIDES the raphides, another and more insoluble inorganic material, silica, is met with abundantly in certain orders of plants, not in a crystalline form, nor contained in the interior of cells, like the raphides, but diffused generally throughout the structures in which it occurs, and this connexion is so intimate and equable, that it forms a complete skeleton of the tissues after the soft vegetable matters have been destroyed; in fact, the part it plays with reference to the organized tissues in which it is deposited is precisely analogous to that existing between the animal and earthy elements of shell. Silica exists in such great abundance in the cuticle of a plant known as *Equisetum hyemale*, or Dutch rush, that on this account the stems are employed by carvers in wood and modellers in clay as a substitute for sand-paper.

When the stems are rubbed together, a grating noise is heard, as if they were composed of glass. In the *Graminaceæ*, especially the canes, silica is also very abundant, but is by no means limited to this order of plants. It is contained principally in the cuticle and in the various structures that are developed from it, such as hairs, spines, &c.; but in some instances layers of cells lying much deeper than those of the cuticle also abound in silica, and it may be met with in woody fibres and in spiral vessels.

In certain of the canes, as the bamboo, silica sometimes collects in large solid masses in the interior of the joints, forming the substance called "tabasheer." It would seem that in this case, the silica should be viewed in the light of a secretion, as it is poured out in a liquid state into the cavity of the bamboo, and I possess a specimen in which a spiral vessel, lying in the cavity of the joint, has been entirely surrounded by the tabasheer.

It is generally known that after the burning of haystacks, masses of irregularly-shaped, but perfectly formed glass, are always to be found among the ashes; these result from the fusion of the silica contained in the cuticle of the hay, in combination with the potash of the vegetable tissue, by which a silicate of that base (or glass) is formed.

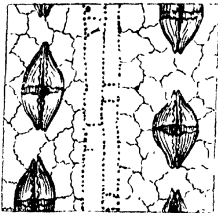
In a portion of the bark of a tree from Ceylon, the name of which I have never been able to ascertain, the

amount of silica is so great as to cause it to be employed in the manufacture of pottery.

In order to display effectually the siliceous matter in plants, it is necessary to expose the tissue under examination to the flame of a blowpipe, or better still to boil it for some days in nitric acid. By these means the organic portion is entirely destroyed, and the silica withstanding these destructive agents, remains as a perfect model or cast of the original tissue.

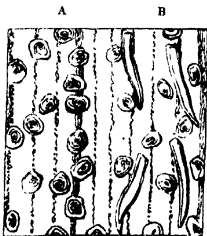
The stem of *Equisetum hyemale*, after having been

FIG. 34.



A portion of the cuticle of *Equisetum hyemale*, after long boiling in nitric acid.

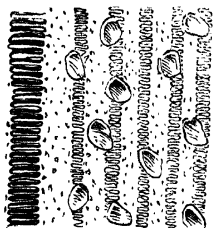
FIG. 35.



A portion of the cuticle of a leaf of the *Bamboo*.

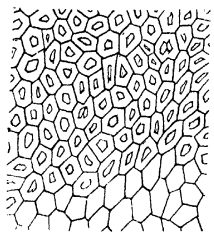
boiled and macerated in nitric acid for a considerable period, is a mass of pure silica, and, as represented in Fig. 34, not only do the forms of the cells of the cuticle remain, but even a considerable amount of the detail of the stomata, as shown in the rows of small oval bodies with serrated markings. In the leaf of the bamboo, Fig. 35, of which one part A has been imperfectly, and another B perfectly decarbonised, an exact model, or cast in silica, of the original specimen still remains; the more complete the decarbonisation the whiter is the silica. On the surface of that part of the leaf, shown at B, even

FIG. 36.



A portion of the husk of a grain of *Wheat*.

FIG. 37.



A portion of the cuticular and subcuticular layer of cells of the *Manilla cane*.

the hairs are plainly exhibited. In the husk of a grain of wheat, Fig. 36, not only the cells of the cuticle and layers of cells beneath, but also the fibres of the spiral vessels are silicified.

The smooth, glassy outer surface of cane present, is entirely due to silica; for if a thin slice of the cuticle be removed and exposed to the flame of a blow-pipe, or to the action of nitric acid as in Fig. 37, from the Manilla cane, not only every cell of the cuticle remains beautifully defined, but in this instance, the layer of cells immediately beneath; these have no nuclei, and are seen at the

bottom of the figure, the cuticular layer having been removed from this part.

Of all the grasses used as food by man, rice contains the largest proportion of silica. This is demonstrated by boiling the husk of the rice grain in nitric acid to remove the organic matter, after which the microscope gives evidence of the large quantity of silica contained in the husk. This circumstance accounts for the worn and flattened surfaces of the teeth of those races of men

FIG. 38.



Portions of
woody fibres
from the husk
of the *Rice*.

that live almost entirely on raw rice; examples are found in the skulls of Malays in the Museum of the College of Surgeons. This condition of the teeth frequently enables us to distinguish the animal or vegetable nature of the food by which the individual has been supported.

In the husk of the rice, the woody fibres are also coated with silica. In most specimens the woody fibres are abundant, some of them, as seen in Fig. 38, presenting peculiar serrated margins somewhat like those of the fibres of the crystalline lens of the cod-fish; others, as shown at *b*, are smooth.

As I have already stated, the modifications of the epidermic cells of plants partake largely of the siliceous deposit, and this is particularly the case with the hairs or setæ which stud the surface of the husk of the oat, wheat and other grains. I may here refer to a very interesting pathological circumstance in connexion with these minute and seemingly insignificant hairs. The occurrence of intestinal concretions of anomalous character, and of no ordinary size, was at one time far from uncommon in this country, especially in the north of England and in Scotland, and many such specimens are preserved in the Museum of the College of Surgeons. Some of them are of considerable bulk. One of these was

brought to the College many years since, for the pur-

FIG. 39.



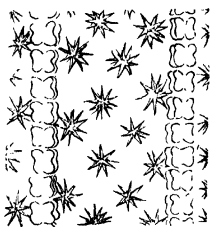
Hairs from
the palea
of an Oat.

pose of ascertaining its nature and the *rationale* of its formation. Mr. Clift, our late respected Conservator, suggested that it might be in some way connected with the husks of the oat becoming mixed with the oatmeal, which forms a staple article of food among our northern countrymen; but it remained for the microscope to confirm and complete the explanation, and Dr. Wollaston proved by the assistance of that instrument the identity of the elements of these calculi, with the hairs or setæ from the palea of a recent oat. Two of these hairs are shown in Fig. 39. Similar calculi

are sometimes formed by the accumulation of the hairs of the wheat husks, when brown bread is extensively used as an article of diet.

The *Pharus cristatus*, an exotic grass, is remarkable

FIG. 40.



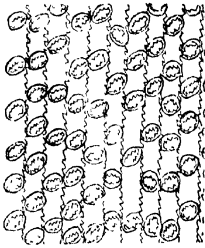
Portion of the cuticle of a leaf
of *Pharus cristatus*.

for the arrangement of its silicified cells. In this grass, two rows or masses of silica, somewhat resembling an hour-glass in shape are arranged in two sets; between these, stellate masses like raphides, are interspersed. Both forms are illustrated in Fig. 40, but never

having seen any specimen of the grass in its natural condition, I am unable to form a

conclusive opinion as to their nature. One of the com-

FIG. 41.



Portion of palea of *Festuca pratensis*.

mon meadow grasses, *Festuca pratensis*, here also requires notice. In the paleæ, cups of silica as they have been termed by the Rev. J. B. Reade, are very abundant. In the specimen represented, by Fig. 41, which is a portion of one of the paleæ in the natural state, longitudinal rows of these cups may be observed; the hairs also on their edges are exceedingly sharp, and abound in silica.

The leaves of most species of *Deutzia* are remarkable for having stellate hairs developed from the cuticle

FIG. 42.



Siliceous cuticle from the under surface of the leaf of *Deutzia scabra*, exhibiting sinuous cells and stellate hairs.

of both their upper and under surfaces; in Fig. 42, some of these are represented. This cuticle, in common

with the other examples already mentioned, exhibits a beautiful series of colours under polarized light.

In the cuticle of the petals of a Mallow *Malva sylvestris*, nearly every cell contains a stellate mass of calcareous matter, but as the masses are all crystalline, they are probably only raphides.

While noticing silica in plants it will be well to make mention of the great abundance of this substance in the beds of our ponds, streams, and rivers, and in the waters of the ocean, formed by the accumulated remains of countless myriads of organized beings; whether these are animal or vegetable is still a matter of contention between botanists and zoologists; the former classing them with the *Algæ*, the latter styling them *Infusoria*. They may, however, be regarded as cells, having their walls strengthened by a coating of silica, which like that of the cuticles before mentioned, is probably a secretion, and indestructible both by fire and acids.

According to botanists, the *Algæ* are divided into five natural orders, viz.: *Diatomaceæ*, *Confervaceæ*, *Fucaeæ*, *Ceramiaceæ*, and *Characeæ*. Of these the *Diatomaceæ* are characterised as "angular fragmentary bodies, brittle, and multiplying by spontaneous separation." This order is divided into three genera, viz: *Cymbelleæ*, *Hydrolineæ* and *Desmidiæ*; the two first have a siliceous, and the last a horny skeleton. All are remarkable for their beauty of form, as well as for the markings on their surfaces, which are so delicate in many cases, as not only to be employed as a test of the

defining qualities of a microscope, but, in some instances, their minuteness is such as even to defy the highest magnifying powers we at present possess, to render them visible.

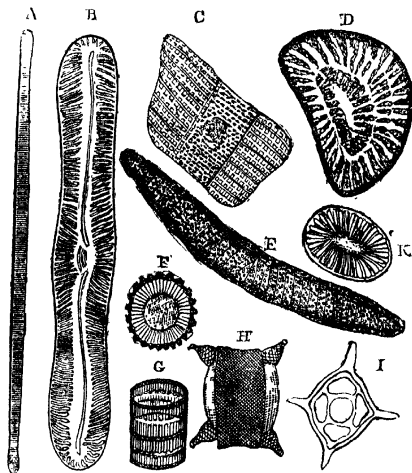
The *Diatomaceæ* inhabit both salt and fresh water ; the *Desmidiæ* fresh water only ; these last have lately been classified and arranged by a member of our own profession, Mr. John Ralfs, and in his excellent work you will find all that relates to their structure and mode of development. If the *Diatomaceæ* be animals, the *Desmidiæ* are certainly vegetables, Mr. Ralfs having detected in them the presence of starch.

The *Diatomaceæ* possessing siliceous skeletons, require a brief notice ; a good example is the *Isthmia obliquata* found on our coasts, attached to *fuci*, and remarkable for the elegance of its form and markings. A single shell is represented by c in Fig. 43. The *Isthmia*, although having a siliceous shell or covering, is claimed by the botanists, and the first figures of it were given in Sowerby's "British Botany." Many of the *Diatomaceæ*, on account of their silica, are not only employed largely in the arts, as a material for polishing metal and other hard structures, but in the form of a light white powder, resembling magnesia, are said to be used as an article of food, being known in Germany, as the *berg-mehl*, or mountain-meal. The *berg-mehl* consists principally of the remains of *naviculæ*, one of which is represented by B, in Fig. 43.

In certain parts of the world, as in Germany, and

especially in America, there are strata of infusorial remains, many miles in extent. The city of Richmond, in Virginia, is built upon a stratum eighteen feet deep,

FIG. 43.



A, *Synedra*. B, *Navicula grandis*. C, *Isthmia obliquata*. D, *Campylo-discus clypeus*. E, *Eunotia*. F G, *Gallionella sulcata*. H, *Zygoceros rhombus*. I, *Dictyocha fibula*. K, *Cocconeis*.

and upwards of thirty miles in length, which is shown by the microscope to consist of little else than well-marked infusorial remains, some of which are represented by E, F, G, H, I, K, in Fig. 43.

These minute creatures once lived in the water, from which they had the power of separating the silica, in the same manner as their representatives of the present

day—as one generation died off, it was replaced by another; and so, in process of time, was a stratum formed.

In Bohemia there is an infusorial earth termed *Kieselguhr*, which is remarkable for containing peculiar shield-shaped discs, termed by Ehrenberg, *Campylodiscus clypeus*; one of these is represented by D, in Fig. 43.

On the shores of South America, and in many islands of the Pacific, sea-birds, principally penguins, resort and deposit their excrement, which, in the lapse of ages, has accumulated so as to form masses of enormous extent and depth; and thousands of tons have been brought to this country as a manure, under the name of guano. Guano consists of a mixture of flesh, bones, and sand, together with various salts of potash, lime and ammonia. When examined microscopically, a great abundance of beautiful siliceous skeletons of *Diatomaceæ* are found amongst it; and curiously enough, the best samples of guano contain the greatest number of these remains, which were first detected by my late brother in 1845. The infusorial skeletons are chiefly circular, and many of them of a blue colour; they are the siliceous shells of animalcules once inhabiting the depths of the ocean, and which had been swallowed by the fishes, on which the penguins feed, but had not been digested; they belong principally to three genera: *Actinocyclus*, *Gallionella* and *Coscinodiscus*, and are no doubt of the same species with others still living in the sea in the neighbourhood of the Guano Islands. Now, when we

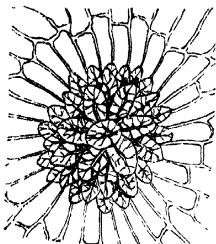
consider the vast amount of silica that must be removed from the soil with the straw of wheat, barley, oats, and other grasses, it must be evident that a supply of this substance ought to be restored to the soil in order to insure good crops ; hence, it follows, that the value of good guano as a manure may depend, not entirely upon its ammonia, lime, and potash, but in a certain degree also upon the silica it contains.

LECTURE V.

SCLEROGEN.

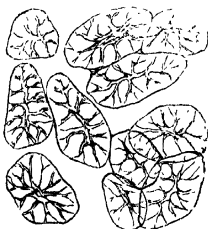
I NOW proceed to speak of another kind of deposit in cells, which still retains the name of *sclerogen*, originally given it by Turpin ; this deposition always takes place in the interior of the cell, but rarely if ever completely fills it, a central cavity, and certain radiating tubes or canaliculi being left at intervals in the deposit. In the Histological Catalogue of the Museum of the College of Surgeons, all the principal varieties of the deposit of *sclerogen*, are classified and described under the name of Hard tissues, and contrasted with bone and teeth, which form the hard tissues of animals. Those who are in the habit of eating *Pears* will remember, that near the centre of the fruit, and in the neighbourhood of the seeds, there is something which grates between the teeth : it is known to botanists as the Gfitty tissue,

FIG. 44.



Thin section of *Pear*, showing a mass of gritty tissue amongst the cells.

FIG. 45.



Isolated cells from the sclerogenous, or gritty tissue of the *Pear*.

and consists of a number of cells aggregated together in small bundles, somewhat in the shape of a star, or a mass of conglomerate raphides. When a thin section of *Pear* is examined with a power of ninety diameters, as shown in Fig. 44, these stellate masses are readily seen amongst the cellular tissue; but when a

higher power is employed, as of two hundred and fifty diameters, and the cells have been slightly separated

from each other by maceration or boiling (Fig. 45), each exhibits a distinct central cavity with tubes radiating from it, and the solid deposit contained within the cell, is almost as clear and transparent as quartz, and refracts light very strongly.

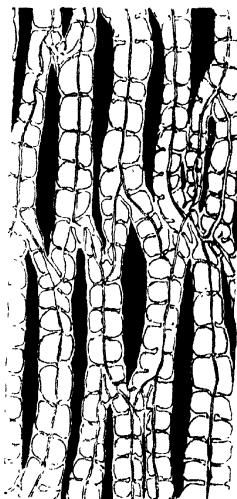
This is the *sclerogen* of Turpin, and it is the same mate-

rial that gives hardness to the stone of the *Plum*, *Apricot*, *Peach*, &c., to the shell of the *Cocoa* and *Coquilla nut*, and which is so dense and white in the fruit of a *Palm*, *Phytelephas macrocarpa*, as to have obtained the name of vegetable ivory.

Some of these structures are so hard as to be employed in the arts for various purposes; the albumen

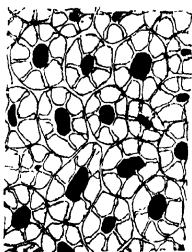
of the *Ivory-nut*, and shell of the *Coquilla-nut*, being turned into handles for walking-sticks, umbrellas, and other articles as a substitute for true ivory. The *Coquilla* is a species of *Cocoa-nut*, and full two centuries ago received the name of *Cocos lapidea* from its stony hardness. The *Ivory-nut*, when first imported into this country is so soft as to be readily cut with a knife, and is of a milk-white colour, but it soon hardens, and although so very dense, yet, when cut sufficiently thin, still exhibits its cellular character. It is composed of long oval cells, having large elongated central cavities, from which, numerous canals radiate towards the margin

FIG. 46.

Vertical section of the *Ivory-nut*

of the cell, at this point, as shown in Fig. 46, they are considerably dilated. It is curious to observe that the pores or canals in adjoining cells almost invariably correspond at their circumferential extremities, and yet they in no case meet or otherwise communicate, the intervening cell wall being always present, as seen in Figs. 46 and 47. In a transverse section of the same nut, Fig. 47, the size of the central cavity, and the pores coming off from it as

FIG. 47.

Transverse section of *Ivory-nut*.

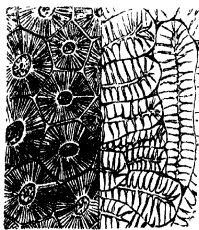
so many radii, are seen; their dilated ends are well shown, also the fact of their non-communication with adjoining pores, and the presence of the cell wall.

In specimens mounted in preservative liquids, the *canaliculi* and central cavities become filled with the fluid;

but those mounted in a dry state contain air, and the points above mentioned are more clearly shown, as both cavities and canaliculi are perfectly black, and they have precisely the appearance of bone cells, the surrounding parts being transparent.

The outer coating or husk of the *Ivory-nut* is of a

FIG. 48.

Vertical section of the testa, or husk of the *Ivory-nut*.

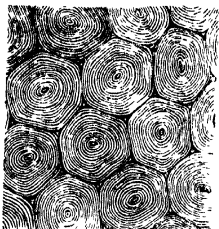
brown colour, and exhibits a structure quite different from that of the white interior. Some of the cells, as shown at *a*, in Fig. 48, are, when transversely divided, of hexagonal figure, and consist of a small central cavity, with a very great number of minute equal sized pores or canaliculi radiating from it towards the wall of the cell. In imme-

mediate connexion with these cells, as shown at *b*, are others divided longitudinally, in which the system of

pores is well shown. A curious point in this section is, that cells appearing so truly different in structure, should occur so close to each other, and that there should be no gradual transition from one to the other.

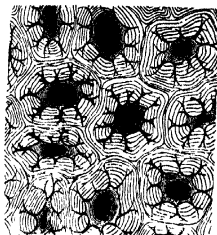
In the cells of some plants the deposit takes place in concentric layers. In a section of the Snake-wood, *Brosimum guianensis*, a wood not unfrequently used in the manufacture of bows for the archer, there are many large ligneous cells, in which the deposit has taken place in concentric laminæ, the pores running through them being small and few in number; and the central spot, although of very minute size, is occupied by a mass of rich brown resinous matter. These cells have been already described, and one of them is represented by D, Fig. 4; the same kind of tissue is found in the cones of the *Common Fir*, which consist of elongated cells, nearly full of deposit. Four of these, divided vertically, are represented by G, in Fig. 4, and a mass of the same in transverse section by H, in the same figure. In the old ligneous cells of the bark of the *Beech*, the concentric deposit is remarkably well seen with scarcely any trace of pores, as illustrated by Fig. 49. A singular form of laminated deposit, combined with a branched condition of the pores or canaliculi, is found in the seed of the *Star-anise* represented in Fig. 50. It is best seen in specimens mounted in *Canada balsam*, and when the central cavity and pores of the cell are full of air. The laminæ are well shown in sections of the cells, but the branching of the pores, which are very

FIG. 49.



Old ligneous cells of the bark of the *Beech*, exhibiting concentric deposit.

FIG. 50.



Cells in the testa of the seed of the *Star-anise* (*Illicium anisatum*).

numerous, can be better studied when the outer surface of the cell is in focus, or when a thin layer of the cells is uninjured in the preparation of the specimen.

A knowledge of these hard structures is often of considerable importance, much more so, indeed, than many are apt to imagine. The following is an example of the practical utility of such an acquaintance with minute structural anatomy: About two years since, I received from a medical gentleman in the country, some specimens mounted as microscopic objects, that had been passed from the bowels by a female. One of them I found to be the cuticle of a plant, and this turned out subsequently to be the cuticle of a *Gooseberry*; the other puzzled me, but I made up my mind that it also was of vegetable origin, and that it was, in all probability, the testa of some seed. I wrote to my correspondent to this effect, but the patient denied having eaten any dried fruit for the space of twelve years, and the physician, believing the statement of his patient, considered that the

microscopist was in error. I, however, still maintained my point, and, when preparing the series of specimens known as hard tissues, for the Histological Catalogue of the College of Surgeons, I examined, among other things, the *Tamarind*, and in the testa of the seed found the disputed structure. I subsequently learned that the patient was the daughter of a grocer, and might have had free access to the tamarind jar. This is another instance of the value of the microscope to our profession.

FIG. 51.



Portion of the
testa of the seed of
the *Tamarind*.

FIG. 52.

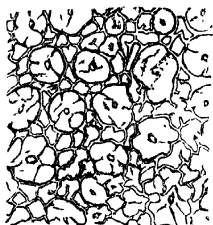


Portion of the
testa of the seed of
Croton tiglium.

A portion of this specimen is represented in Fig. 51. It consists of a series of elongated cells or woody fibres, which exhibit pores on their margins, and occur in several laminae; the direction of the cells in one part of a lamina is often nearly at right angles to that in close proximity to it; the entire testa is exceedingly tough, and no doubt very indigestible. A somewhat similar tissue to that above described exists in the core of the *Apple*, but the cells are much coarser than those of the *Tamarind*.

In the *Croton-oil* seed, the cells are remarkable for their minute size, being much smaller than in any other plant I have yet examined; they, however, exhibit very well the central cavity and radiating pores. A portion of one of the seeds is represented in Fig. 52.

FIG. 53.



Section of the testa of the seed
of a *Euphorbiaceous* nut.

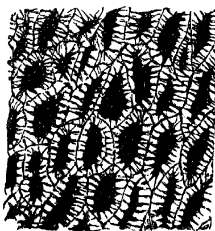
In certain *Euphorbiaceous* nuts, the sclerogen is of a brilliant crimson colour, and in the specimen, represented by Fig. 53, the cells are of a peculiar shape, having indented or wavy margins, and when light is transmitted through such objects, the red colour is so bright as to interfere with distinct definition.

Each cell is nearly filled with the crimson deposit.

In the *Walnut*, *Cocoa*, and *Hazel-nuts*, the same kind of tissue is found ; in these, the pores with their central cavities, resemble in a most striking manner the cells of bone ; but, as I have so often stated, in vegetables the cell-wall always remains, forming a strong barrier between the ends of the pores or canaliculi of adjoining cells ; whereas in bone, the cell-wall disappears, and the canaliculi anastomose.

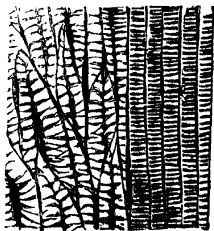
In the specimen represented by Fig. 54, the cells

FIG. 54.



Transverse section of the shell of a
Cocoa-nut.

FIG. 55.



Vertical section of the shell of a
Cocoa-nut.

in a transverse section of the shell of a *Cocoa-nut* are seen; and in Fig. 55, a horizontal section of the same shell, not only the thickened cells are shown, but close to them a part of a bundle of peculiar vessels, somewhat like those occurring in *Ferns*.

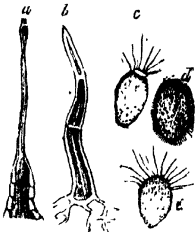
Spiral vessels are occasionally met with both in the shells of the *Walnut* and *Hazel-nut*.

In addition to the substances already described as examples of the more common contents of cells, a few of a peculiar nature demand some notice.

Certain plants are provided with offensive weapons, some of which are known as stings, being (as in the *Nettle*) elongated cells or hairs developed from the cuticle, and usually of a conical figure. They contain a poisonous or irritating fluid, in which, in some cases, a cyclosis or circulation is visible. When examined with a power of one hundred diameters, as represented by *a, b*, in Fig. 56, each sting is seen to have either

a minute bulbous or triangular free extremity attached by a narrow neck to the apex of the shaft; the part connected with the cuticle is much expanded, and around its base are certain more or less polygonal cuticular cells. The contents of the hair are always in a state of tension, and when the hand is passed

FIG. 56.



a, b, stinging hairs of the *Nettle* (*Urtica dioica*); *c, d, e*, ciliated spores of *Conferva*.

along the part of the leaf on which these stings are situated, the free extremity is rubbed off, the point of the sting perforates the skin, and, by the pressure of the cells at the base of the hair, the poisonous matter is forced into the wound in a similar manner to the venom from the fang of a serpent.

We now arrive at the most highly-organized products of secretion of the vegetable cell, viz.: those especially engaged in the development of future plants; they are called *Phytozoa*, or plant-animals, being the representatives of the *Spermatozoa* in the animal. They appear to have been first discovered by Mr. Cornelius Varley, in 1833, in that part of the fructification of the *Chara vulgaris* known as the globule, and have since been noticed by Meyen and Unger in mosses, and by Nägeli in ferns.

Mr. Varley's account of these bodies is so true to nature, that I may perhaps be permitted to extract a short paragraph from his paper in the second volume of the "Transactions of the Microscopical Society:"

"The ripe globule spontaneously opens. The filaments also expand and separate into clusters. They are so numerous, that I have not been able to decide upon their exact number.

"The tube-like filaments are divided into numerous compartments, in which are produced the most extraordinary objects I have ever observed of vegetable origin. At first they are seen agitated and moving in their cells, where they are coiled up in their confined

spaces, every cell having one. They gradually escape from their cells, by what means or through what opening I have not been able to ascertain, and the whole field soon appears filled with life. They are generally spirals of two or three coils, and never become straight, though their agitated motion alters their shape in some degree. They have at their foremost end a filament so fine as only to be seen by its motion, which is very rapid and vibratory, running along it in waves.

“These objects, although they have every appearance of life, swim about with no apparent consciousness of each other, or any choice of direction. Their filamentary end goes foremost; when they come into contact with each other they become entangled, and their motion is hindered. This does not cause any retreating action or attempt at separation except by accident.

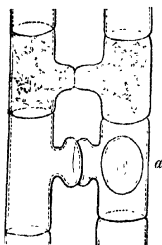
“They appear to be an example of life without self-will or choice. Their motions gradually slacken, and in about an hour they become perfectly still.

“If a globule be forcibly opened before it is ripe, the filaments will give no indication of life.”

Unger has described them in *Sphagnum* as *Infusoria*, under the name of *Spirillum*; they have been the subject of great controversy, and Schleiden, denying their animal nature, has stated that they are nothing more than fibre in an early stage of development. From what I have been able to observe, I think that Schleiden's notion is decidedly erroneous, and that they are strictly analogous to the *Spermatozoa*.

In some of the lowest plants, as the *Confervæ*, an act, called by botanists *conjugation*, takes place. Two filaments lie side by side, and very soon a nipple-shaped growth is protruded from opposite points of the filaments, these touch and eventually communicate; one cell becomes empty, and in the other a spore is developed. The spore makes its escape from the parent

FIG. 57.



Conjugation of *Conferva*; *a*, spore in process of development.

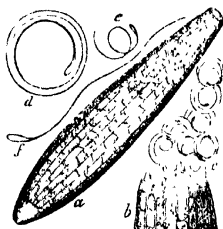
cell, and swims about very actively by means of cilia attached to some part of its outer surface. In some species there is a pink spot in the centre of the spore, and such spores are no doubt not unfrequently described as *Infusoria*. The conjugation of a *Conferva* is shown in Fig. 57, and at *a*, a spore in process of development. Spores provided with cilia are represented at

cc and *d*, in Fig. 56.

If we examine mosses of the genus *Sphagnum* and *Polytrichum*, in the spring, we find among the parts concerned in reproduction, certain elongated bodies termed *Antheridia*. If one of these be ruptured, a number of cells make their escape, and, if this be done in water, in a few moments we notice, with a power of two hundred and fifty diameters, the rapid movement of a spiral filament or phytozoon, in each cell. The filament has a globular head and a long tail, exactly like that of a *Spermatozoon*. When the *phytozoa* escape from the

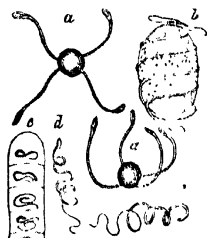
cell, their true form may be made out, and they will be seen to be precisely of the shape exhibited in Fig. 58; *a* representing one of the *antheridia*, *b* a portion of the

FIG. 58.



Reproductive parts of *Polytrichum commune*: *a*, antheridium; *b*, portion of an antheridium more highly magnified; *c*, cells escaping from ruptured antheridium; *d*, cell containing a phytozoon; *e*, *f*, phytozoa detached from the cell

FIG. 59.



a, *a*, spores and elaters of an *Equisetum*; *b*, spores surrounded by the elaters; *c*, portion of filament of *Chara vulgaris* dividing phytozoa in the cells; *d*, *d*, phytozoa of *Chara vulgaris* taken out of the cells.

same ruptured, with numerous cells escaping. Each (as shown at *c* and *d*) contains a spiral filament, which, when detached from the cell, presents the appearance represented by *e* or *f*. The spores of the common *Equiseta* or *horse-tails* also possess a power of spontaneous motion, depending, however, on hygrometric conditions of the atmosphere. Each spore, as shown at *a a*, in Fig. 59, consists of a central portion with three or four clavate filaments attached to it which are denominated *elaters*. In some states of the spore, as represented by *b*, the elaters are seen surrounding it in a spiral manner; in others, as shown at *a a*,

they will be found standing out in straight lines from the spore. But the most curious point connected with these elaters is the rapidity with which they embrace the spore when slightly moistened by the breath. If the moisture of the breath fall upon them, they will immediately coil themselves around the spore, and almost as quickly resume their original position, and this may be repeated an indefinite number of times. It has been considered by some persons that the phytozoa resemble the elaters, but that their motion is continuous. For the sake of comparison, the phytozoa of the *Chara vulgaris* are shown in Fig. 59; at *c*, a portion of one of the filaments is seen, it is composed of a series of cells of a somewhat square figure, arranged one above the other; in each cell is a phytozoon. Two of these, detached from the cells, and more highly magnified, are represented by *d d*.

LECTURE VI.

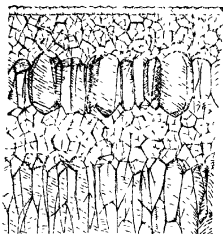
FIBRO-CELLULAR TISSUE.

•
WE now arrive at a class of cells which, for the sake of distinction, may be termed compound, from the circumstance of their being composed of membrane and fibre; they occupy definite positions in plants, and form the tissue known as the fibro-cellular. The cells are of a more or less oval figure, and the fibre often attains a very large size, even as much as $\frac{1}{3000}$ th of an inch.

Fibro-cellular tissue is common in the leaves of many orchidaceous plants, and occurs abundantly in the testa of seeds. I have already mentioned the existence of this tissue on the testa of the seed of *Collomia grandiflora*, in which the cells containing a spiral fibre are protruded from the surface after the seed has been moistened with water. The leaf of an Orchis, *Pleurothallis ruscifolia*, exhibits, by vertical section, a large

number of angular cells (Fig. 60) containing spiral fibres. Immediately beneath the cuticle, on the upper edge of many of the sections, a row of small oval cells may be seen, in which the fibre is of very large size,

FIG. 60.



Vertical section of the leaf of *Pleurothallis ruscifolia*, showing fibro-cellular tissue *in situ*.

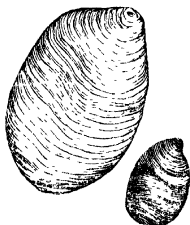
FIG. 61.



Cells of fibro-cellular tissue of *Pleurothallis ruscifolia* more highly magnified.

and in some cases unrolled. If this layer of cuticle

FIG. 62.



A, single cell of the leaf of *Oncidium stramineum*. B, cell from testa of the seed of *Cobaea scandens*.

be peeled off after some slight degree of maceration, and the attached surface examined, a beautiful view of the fibro-cellular tissue, as shown by Fig. 61, is afforded; the terminations of the fibres being seen at the free extremity of the cell. These cells may be isolated from* the leaves of most *Orchidaceous* plants, as in *Oncidium stramineum*, Fig. 62, A, one of the finest

FIG. 63.



Elongated cell
from the leaf of
Saccolabium gut-
tatum with spiral
fibres crossing.

examples of the size of the cells and spiral fibre. Detached cells of *Pleurothallis ruscifolia* have already been represented by E and F, Fig. 4.

In the leaves of another Orchis, *Saccolabium guttatum*, there are very long cells, in which the spiral fibres run obliquely, and cross each other at right angles, whereby a series of diamond-shaped markings are produced. One of these cells, obtained by maceration, is represented in Fig. 63, as seen under a magnifying power of two hundred and fifty diameters.

The testa of the seed of *Cobæa scandens* yields, by maceration, the isolated fibrous cells represented in Fig. 62, B; they are of much smaller size, and contain a fibre remarkable for its extreme tenuity and the number of its coils.

Another form of fibro-cellular tissue occurs in the testa of the almond, in which the fibre is interrupted, and the cells approach in character to those termed porous cells. Similar cells exist in great abundance in certain seeds, whose testæ project laterally, forming thin membranes, or wings as they are called by botanists. In a specimen from the *Sphenogyne speciosa*, represented by Fig. 64, a delicate layer exists, composed of elongated cells of fibro-cellular tissue; in another spe-

cimen (Fig. 65), from the seed of a *Bignonia*, the cells are longer and the fibre coarser than in the pre-

FIG. 64.



Portion of testa of the seed of
Sphenogyne speciosa.

FIG. 65.



Portion of testa of the seed of a
Bignonia.

ceding. In the seed of *Lophospermum erubescens*, in which the thin membranous wing surrounds the entire circumference of the seed, the cells with their spiral fibres are well shown. The most remarkable specimen of wing, however, and one in which this tissue is largely developed, occurs in a plant, from the East Indies, *Calosanthès Indica*, the wing being more than an inch in length on each side of the seed.

DOTTED OR POROUS TISSUE.

The variety of tissue known as the *porous*, is formed by an unequal deposit of secondary matter on the interior of the cell wall; the spaces pre-occupied by the deposit, being thinner than the other parts, produce

the appearance of pits or pores. It is one of the most common vegetable tissues, and is generally met with in the pith and other light parts of plants. The material known as Chinese rice-paper, is not really *paper*, but a thin shaving of a species of the genus *Æschynomene*. I have often heard ladies complain of the difficulty of getting the colour to lie smoothly on this material, which is readily accounted for by the fact that it is composed of a series of large cells (Fig. 66), the walls of which are minutely porous. A spurious kind of rice-paper, procured from a species of *Desmanthus*, (*D. natans*), is still more difficult to draw on than the last; the walls of many of the cells being dotted with large pores.

FIG. 66.

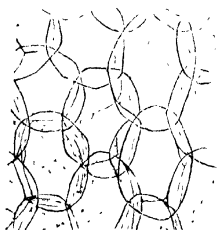
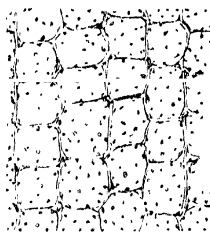
Thin slice of *Chinese rice-paper*
(*Æschynomene*).

FIG. 67.

Porous tissue of the *Dragon-palm*.
(*Dracæna draco*).

The most striking example of porous tissue is that from the oldest living inhabitant on the surface of our globe, the *Dracæna draco*, or *Dragon-palm* of Tene-riffe. In a section I possess of this *Palm*, the wall of every cell (Fig. 67), however small, is covered with

large pores. In all the examples above-mentioned, the cell wall is invariably present, but there are instances when the cells have become old, of the cell-wall disappearing, and true pores being formed.

WOODY TISSUE.—This tissue, which makes up almost the entire bulk of certain plants, is by far the most useful and important to man of all those occurring in the vegetable kingdom, since it supplies material to every branch of art, and to it we are indebted for our linen, ropes, cordage, &c., to say nothing of paper.

It consists of elongated transparent tubes of great strength, but varying much in size in different plants; each tube is more or less pointed at both extremities, and in some cases the tubular part has become almost solid by the internal deposition of new matter, so that the trace of the central cavity is only indicated by a line. Such tubes are remarkable for their toughness, and have received the name of fibres. The outer membrane of the fibre is generally structureless; but in the *Flax* and other plants, in which the fibres are of great length, there are here and there traces of transverse markings.

The fibres of *Flax* are aggregated together in bundles, and are separated from the plant for use by a process termed *hackling*, which may be described as an alternation of beating and combing. In the rough condition, in which it is imported from Russia, the fibres have been, to a certain extent, separated by hackling. On its arrival here, it is again subjected to maceration, to a repetition of the hackling, and to the bleaching process in order to reduce it to the white silky condition

required by the spinner and weaver. *Flax*, after its final preparation, consists of bundles of structureless tubes (Fig. 68, A) which are seen separated in Fig. 69, each fibre exhibiting a central line.

Similar bundles of woody tissue occur in the "*China-grass*" of commerce, which is said to be obtained from a plant of the *Nettle* tribe, and is brought to this country in the form of coarse fibres, two of these are represented in Fig. 68, c. After being hackled,

FIG. 68.



A, bundle of woody fibres of the *Flax* plant. B, two of the ultimate fibres of the leaf of the *Pine-apple*. C, two woody fibres of the *China-grass* plant.

macerated, and bleached, it is made into very delicate shining linen handkerchiefs, the material of which is

known as *Grass-cloth*. The fibres of the *Phormium tenax*, or New Zealand *Flax*, are much stronger than those of the common *Flax*, but are much more easily broken, in consequence of the outer membrane being excessively brittle. Although these fibres will resist a very considerable force applied to them longitudinally, if tied into a knot so that the fibre is twisted, or if the force be applied transversely, they readily break.

Of all the woody fibres I have examined, those obtained from the leaves of the *Pine-apple* plant appear to be the finest. For the sake of comparison, representations are given of the fibre of *Flax* (Fig. 68, A), of *China-grass* (Fig. 68, c), and of the *Pine-apple* (Fig. 68, B), as seen under a power of four hundred diameters, by which it is well shown that the last is much smaller than either of the others.

It is important, under certain circumstances, to determine the true nature and composition of some of the textures used as articles of clothing, &c., and this is readily done if we bear in mind the characters of the elementary tissues. In linen we find the component threads merely longitudinal, rounded, unmarked fibres, such as have been already figured in *Flax*, Fig. 69 ; but where cotton has been employed solely, or by admixture, its fibres, as shown in Fig. 70, are recognised as flattened and more or less twisted bands, bearing other marks of resemblance to hairs, which, in fact, they are, since in the condition of elongated cells, they line the inner surface of the pods. Fig. 70, represents the isolated

elongated cells of cotton, in which the peculiar characters I have described, are delineated, they may be contrasted

FIG. 69.



Fibres of Flax.

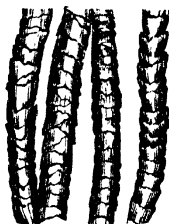
FIG. 70.



Fibres of Cotton.

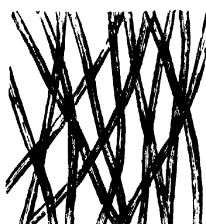
with the figures of true woody fibre, and also with wool (Fig. 71), and silk (Fig. 72), and it will be

FIG. 71.



Wool of sheep.

FIG. 72.



Filaments of silk.

seen that these textile materials are readily distinguishable by the microscope.

Mummies have, at various periods, been brought to this country and unrolled, and it has been a matter of

curiosity to determine the nature of the clothing material, as giving evidence of that in use in the country and age in which they were embalmed. By microscopic investigation of the texture of mummy cloths, it has been shown that the Egyptians used *Flax* only in their manufacture, whereas, in the Peruvian mummy cloths, *Cotton* alone has been discovered. In some fabrics from Otaheite, *Wool* is mixed with *Cotton*, and is recognisable, as shown in Fig. 71, by the zigzag transverse markings on the fibre, which are characteristic of hair.

In the foregoing examples of woody fibre, the membranous walls are structureless, having no visible markings; but other kinds exhibit certain peculiarities of structure, which depend on secondary deposits of *lignine* in their interior. In *coniferous* woods, such as *Deal*, the fibres are not filled with secondary deposit, and consequently remain tubular.

In a transverse section of a fossil *Palm* from Antigua, most of the woody fibres will be found to be occupied by a concentric deposit like that of the *Beech*, represented in Fig. 49. In the *Clematis*, the woody fibres are exceedingly short, and more or less pointed at both extremities; the walls, as shown in Fig. 73, are marked with numerous simple pores. These pores are more evident, and of a compound or bordered character, in a section of *Deal*, Fig. 74, made in the direction of the medullary rays; in every fibre a row of large circular dots or pores may be seen, which are characteristic of

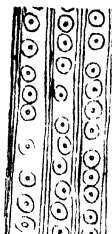
the coniferæ, each pore having a smaller one in its centre. In some woods, and especially in fossil speci-

FIG. 73.



Woody fibres of
Clematis.

FIG. 74.



Woody fibres of *Deal*, exhibiting
bordered pores.

mens of *Araucaria*, three or more rows of pores occur in each fibre.

Spiral fibres may also co-exist with pores, as in the *Yew*, (Fig. 75) each woody fibre of which has two spirals interlacing each other, and one or two pores

FIG. 75.



Section of *Yew*, showing
bordered pores and spiral
fibres.

FIG. 76.



Section of *Araucaria excelsa*
exhibiting large bordered pores
and spiral fibres.

between the interlacements of the fibres where these are most distinct. The co-existence of large pores with a well-developed spiral fibre is best seen in a section of the Norfolk Island pine, *Araucaria excelsa*, (Fig. 76) a tree, which in its own climate, often attains the enormous height of two hundred feet. The nature of the pores, or glands as they have been termed, of the woody fibres of the *Coniferæ* has long been a matter of dispute.

The foregoing illustrations have been taken from compact woods, but in certain palms the woody fibres are so hard and stiff, and the bundles so easily separated that they are employed for making brushes. The larger and coarser bundles are made into brushes for sweeping the streets, while the smaller are used for scrubbing and other lighter purposes.

In a section of the stem of the cocoa-nut palm, the bundles of woody tissue are of a brown colour, and form the spots seen upon the surface; the surrounding texture being so compact as to bind them firmly together. A transverse section of one of these bundles affords a striking example of the interior of a woody tube almost entirely filled up by dense secondary deposit, and accounts for the strength of the individual fibres. In many light woods, especially one from China, the name of which I have not been able to obtain, but which from its softness, is employed as a substitute for cork in the lining of insect boxes, the woody fibres are short, of rather large diameter, and, instead of being

filled up with hard matter, as in the cocoa-nut, their interior is occupied with granules of starch, arranged in single, double, or treble rows; these might very easily be mistaken for pores, but their true nature is readily detected by the addition of iodine.

WOODY TISSUES.

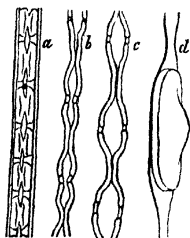
When speaking of the various kinds of woody tissue employed in the arts, I mentioned ordinary *Flax*, *China Grass*, and *Hemp*, and stated that, from the peculiarly hard nature of the outer coating of each fibre of the latter, it was rendered very brittle when twisted. I then remarked that linen is at all times more difficult to work, and to absorb colouring-matter, than cotton, which may perhaps, be accounted for by the density or toughness of the woody fibre; I have since learned that a process has lately been invented by M. Claussen for subdividing the elementary fibres of *Flax* by boiling and steeping, after they have been hackled and bleached in the usual manner, and specimens prepared in this way are made to imitate not only cotton, but silk and wool. In some samples of *Flax* which have undergone these processes, the fibre has been reduced to the fineness and suppleness of cotton, in another to the texture of silk, and in a third to that of wool. When, however, these

specimens are examined microscopically, the woody fibres will, in most cases, be found entire ; some indeed are ruptured transversely, and others partially separated into finer fibres. Mr. Donlan has proposed another plan of preparing *Flax*, which if successful, will in all probability yield a more durable fabric than any now in use. In this process the fibres of the fresh stems are at once reduced to the smallest conceivable size by mechanical means, without previous steeping or bleaching.

I have already stated that woody fibres are elongated cells, generally more or less pointed at both extremities, and having their walls strengthened or solidified by internal deposit. Occasionally, however, as in *Flax* and *Hemp*, they are marked with tubercles or transverse lines at short intervals ; in some plants, especially those in which the woody fibres are short, as the *Clematis* and *Elder*, Fig. 73, when marked with pores, or little dots, from deficiency of the internal deposit at certain points, these are called simple pores ; but in the *Coniferæ*, represented in Fig. 74, the pores are surrounded by a larger circular ring, giving to the whole the appearance of a circular cell, with a small central nucleus ; these are called bordered pores, and are well seen in all specimens of coniferous wood. The true nature and mode of formation of these bordered pores was for many years a subject of dispute among botanists ; by some they were supposed to be glands ; others have considered them to be either thick or thin spots in the membranous cell-wall of the fibre, whilst a few have

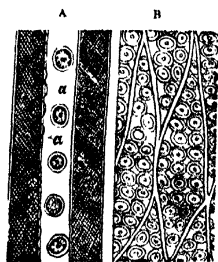
asserted that a hole really exists in the centre of each pore communicating with a similar hole in a neighbouring fibre. It is now, however, ascertained, by improved means of investigation, that these bordered pores are not confined to one fibre, but are formed between two contiguous fibres, and always exist in greatest number on the sides of the woody fibre parallel to the medullary rays. The bordered pores are hollow, their shape is bi-convex, as represented by *c* in Fig. 77; and a small

FIG. 77.



a, section through two contiguous woody fibres of *Salisburia adiantifolia*; *b c*, portions of two contiguous woody fibres of *Deal* (*Pinus Strobus*); *d*, one of the bordered pores of *Pinus Strobus* magnified 500 diameters.

FIG 78.



A, two woody fibres of a fossil coniferous wood, with spiral fibres and bordered pores; *a a*, casts of the interior of the bordered pores. *B*, fossil coniferous wood with three rows of bordered pores.

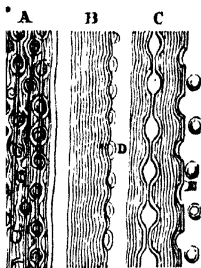
circular or oval spot is visible in the centre of each. In some plants each fibre has one row of pores, in others two and in a few instances, as at *B* in Fig. 78, which is a representation of a specimen of fossil coniferous wood from Kennawha Ohio, the entire fibre is covered with them. In order to get a satisfactory view of these

pores, a tangential section of the wood must be made ; when, as in the specimen of deal (portions of two contiguous fibres of which are represented by *b c*, in Fig. 77,) it will be seen that there are certain oval spaces between these fibres, which have in their centre a pore extending nearly through the entire thickness of the wall of the fibre, but closed by membrane on its outer margin ; a highly magnified representation of one of these pores, showing the mode in which it projects from the side of the woody fibre of the deal, is shown at *d*. The correctness of this account of the real significance of the structure of the *glandular* woody fibre has been strikingly confirmed by the examination of sections of fossil coniferous wood. Some years since, a specimen of fossil wood from Fredericksburgh, in Virginia, was sent to my late brother by Professor Bailey of the Military Academy of West Point on the Hudson, which, on microscopic examination, was found to be coniferous, the woody tissue not only exhibiting the bordered pores, but, in addition, numerous minute spiral fibres, as represented in Fig. 78, A. Some of the disc-like bodies, shown at *a a* in the same figure, and precisely similar to the pores of the fibres, were lying loose. On carefully examining the surfaces of the fibres, similar discs were occasionally found projecting from the outer surface, as represented in Fig. 78, A. It then turned out that these discs were in reality casts in silica of the bordered pores ; in short, the bi-concave cavities shown by *b c* in Fig. 77, had been filled with silica. Thus the description given of

their true nature, after careful observation, was fully confirmed by the fossil specimen.

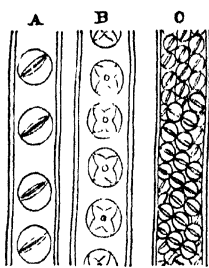
In some of the orchidaceous plants, as those of the genus *Oncidium*, and especially in *Aporum anceps*, small globular bodies are found projecting from the woody fibres, as represented in Fig. 79, A. Sometimes they occur in many rows, as shown at A, or in a single one as at B, or in two rows as at C, each being surrounded by a ring-like marking. These bodies, like those in the fossil specimens, are sometimes found loose, as shown by E, but, the places they occupied, as represented at C, were cavities in the wall of the fibre.

FIG. 79.



A, woody fibre of *Aporum anceps* with four rows of globular bodies. B, woody fibre with one row. C, woody fibre in which the cavities occupied by the globular bodies are shown. D, globular bodies projecting from the side of a woody fibre. E, globular bodies detached from the fibre.

FIG. 80.



A, woody fibre of *Salisburia adiantifolia* with upper surface in focus. B, woody fibre of the same plant with both upper and under surfaces in focus. C, woody fibre of *Cycas revoluta* showing at the upper part the pores on the under, and at the lower those on the upper surface.

In some plants, as in *Cycas revoluta*, the central spot or pore is not round, but more or less oval, and is inclined

at an angle of 45° to the length of the fibre, and the pores lying on one surface have the direction of the central spot at right-angles to that on the other surface; the outer or bordering lines correspond; but if the thin part of a fibre be examined, it often happens that both the upper and under surface are in focus at the same time, and then the appearance of a cell with a crucial nucleus, as shown by c in Fig. 80, will be presented. This fact is even more strikingly exemplified in *Salisburia adiantifolia*, the pores being of much larger size. Portions of two of the woody fibres of this plant are represented by A B in Fig. 80. At A the central pore on one surface of the fibre is shown, and at B the two opposite sides of the same fibre, in which the crucial appearance is most strikingly exemplified. At a, in Fig. 77, a section through two contiguous woody fibres of the same plant is represented, by which it will be seen how these peculiar pores are formed.

LECTURE VII.

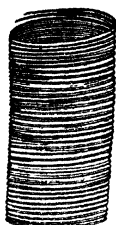
VASCULAR TISSUE.—SPIRAL VESSELS.

Vascular Tissue.—This tissue, bearing as it does the same relation to the growing portion of the plant as the vascular system of animals does to their general organism, may be considered as the most important part of the plant. It forms no exception to the general rule with which we started, that all the textures originate in cells, for these vessels are but elongated cells joined end to end, and ultimately communicating with each other; their walls are in most cases supported either by a complete or modified spiral fibre. These spiral vessels, were called by the older microscopic botanists, *tracheæ*, from their resemblance to the ramifying air tubes of insects; nor is the analogy far fetched, since in either case the tube is kept patulous by an elastic spiral coil of fibre, which has a tendency to unrol itself when

freed from confinement within the vessel. Moreover, in old dry parts of the plant in which their function has ceased, they are found to contain, as in insects, only air, but in the young and growing parts they contain fluid, and floating raphides are found in abundance in the spiral vessels of the young branches or shoots of the common *grape vine*. Spiral vessels, however, differ from the air-vessels of insects in being generally straight and unbranched.

In order to illustrate what I have been describing, it will be well for you to see the tracheæ of the larva of *Dyticus marginalis*; in any of the large branches, as shown by Fig. 81, the presence of a spiral fibre within a membranous tube, will be remarked. For the sake of comparison, a portion of

FIG. 81.



Portion of a tracheal tube of the larva
of *Dyticus marginalis*.

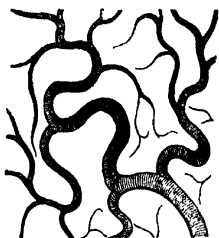
FIG. 82.



Portion of a spiral vessel of
a plant.

a spiral vessel of a plant is represented by Fig. 82, in which it will be seen that the principal point of

FIG. 83.



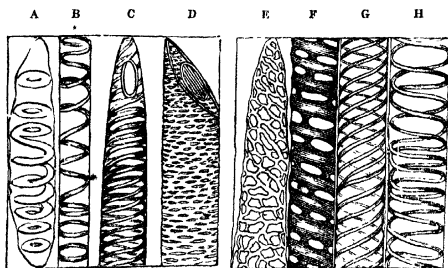
Tracheæ ramifying upon the
stomach of a *Bee*.

distinction is, the size of the fibre in the vegetable being larger than that in the animal. In both, the fibre is within the membranous tube. In Fig. 83, the tracheæ are displayed ramifying on the coats of the stomach of a *Bee*, I may here remark that the tracheæ serve the purpose of carrying oxygen to the blood or nutritious fluid, which in insects is distributed through the system generally, and not in vessels.

Spiral vessels are elongated cells, acuminate at each end (Fig. 86, *a*) with one or more fibres developed within them, and capable of unrolling by the tearing of the delicate membrane of the cell-walls. I have already described the mode of formation of the spiral fibre by a secondary deposit in a spiral direction, on the internal surface of the cell-wall. The spiral vessel is subject to many modifications, in consequence of the variable arrangement of the secondary deposit, and these modifications have heretofore been classed as distinct orders of vessels—the term spiral vessel having been restricted to such as contain one or more spiral fibres, and are capable of being unrolled. Recent and accurate researches have demonstrated, that all the forms of vascular tissue are referable to the same origin: the simple cell with its secondary interrupted deposit. We have already

seen simple ovoid cells containing a spiral fibre; let one of these become elongated and pointed, and we have at once the typical spiral vessel. Other arrangements of the secondary deposit produce the annular, the reticulated, the barred or scalariform, and the dotted ducts of botanists. That such is the case is demonstrated by the occasional presence of the spiral, the annular, the barred, and even the dotted variety in different parts of the same vessel. Nothing is more common in plants, especially among the *Monocotyledons*, than to see the spiral fibre in one part broken up into rings, as in a spiral vessel from the *Opuntia*, Fig. 84, A. Spiral vessels are usually pointed at both

FIG. 84.



A, short spiral vessels, with thickened fibre, from *Opuntia vulgaris*. B, a spiral vessel becoming an annular one. C, spiral vessel having a hole at one extremity. D, dotted vessel with oblique termination and hole in the centre. E, reticulated vessel. F, old spiral vessel with perforations. G, H, spiral vessels with fibre running from left to right.

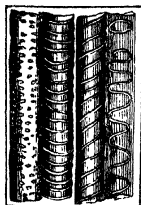
extremities, but occasionally they terminate somewhat abruptly, and a hole is often seen near the extremity,

by which a communication is established with a neighbouring vessel, as in Fig. 84, c, from the petiole of the garden *Rhubarb*. A similar perforation in a dotted duct is represented by Fig. 84, d.

In most spiral vessels the fibre is single, (Fig. 86, a,) it is then called a simple spiral ; in others, two or more fibres running in the same direction form a band, which for distinction is termed a compound spiral vessel (Fig. 86, b) ; sometimes the coils of the fibre separate, and the extremities of each coil uniting form a series of rings ; such vessels are called annular (Fig. 84, A B). In other cases, the turns of the spiral may be connected together here and there by the branching of a fibre, or the development of lateral processes, forming what is termed reticular tissue (Fig. 84, E).

Occasionally the spiral fibre bifurcates, or short longitudinal fibres are developed, which connect the spiral coils, and give the vessel a reticulated appearance ; such vessels represented by E and F, in Fig. 84, occur in sections from the *Balsam*. In other cases, the spiral thread is not so evident, but the interior of the vessel (A, Fig. 91) is marked by long slit-like pores, which are placed regularly one above the other, resembling the rounds of a ladder ; these are termed scalariform vessels, are almost peculiar to *Ferns*, and will be alluded to hereafter. That these are really all modifications of the spiral type, is known by the frequent occurrence of several varieties in one and the same plant, and even section, as in the *Balsam*,

FIG. 85.



A bundle of vessels from the stem of a *Balsam*.

Fig. 85, where in a single bundle, the outermost vessel on one side is dotted, and that on the other annular; between these, spiral vessels occur, with their spires more and more widely separated. This state of things may be also observed in the *Lettuce*, in the root of which plant, bundles of vessels are frequently seen in various

stages of development at one and the same time.

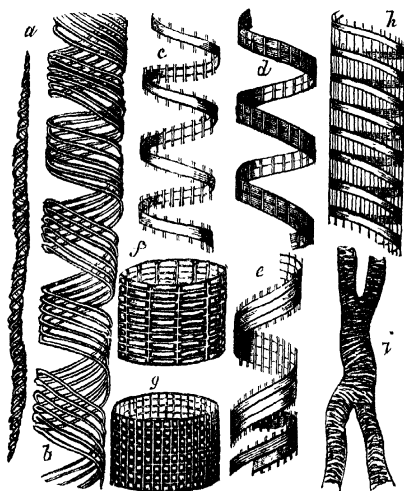
In some plants, and especially in the *Canna bicolor*, the spiral vessels are remarkable for the occurrence of longitudinal as well as spiral fibres. In Fig. 86, *h*, is represented what might be taken at first sight for an ordinary spiral vessel of large size, but, if carefully examined, a series of minute longitudinal fibres will also be observed, and when such a vessel is unrolled, the broken ends of these fibres, as represented by *c h e*, will be found projecting above and below the spirals.

In many cases, both the longitudinal and spiral fibres are of the same size and equi-distant. The vessel represented in Fig. 86, *g*, is covered with square markings, but retains its capability of unrolling. In another specimen, Fig. 86, *f*, from the same plant, the longitudinal fibres, although of the same size, are wider apart than the spirals; the vessel in this case presents markings which are true parallelograms, not squares.

These remarkable vessels have amongst them others,

which are unrolled, and occasionally, as represented by Fig. 86, *b*, you may see very fine examples of the compound spiral vessels before alluded to, as many as

FIG. 86.



a, simple spiral vessel from petal of *Anagallis*; *b*, compound spiral vessel from *Canna bicolor*; *c d e f g h*, portions of spiral vessels of *Canna bicolor* having longitudinal as well as transverse striae; *i*, branching spiral vessels from the stem of a *Leek*.

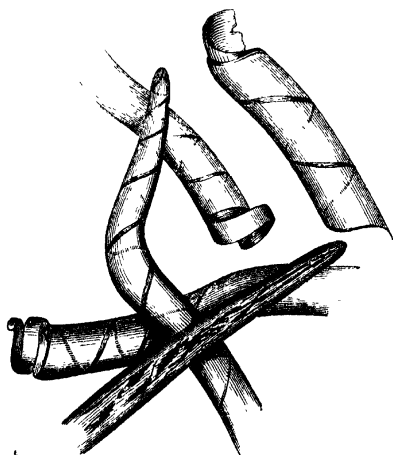
six coils forming a band; I have, however, in some cases, counted as many as twenty-two. Spiral vessels not unfrequently branch; this fact is well seen in the specimen taken from the flowering stem of the *Leek*, and represented by *i*, in Fig. 86.

In all these examples, it may be observed that the

spiral fibres are uniformly coiled from right to left, but in some instances, this is reversed, and left-handed spirals are found, as in the section of a *Palm* from the East Indies, Fig. 84, G, H; it has been suggested that the direction of the fibre may determine that in which the plant coils round an upright pole. The *Hop*, which exhibits these left-handed spiral vessels is also a left-handed climber, which gives support to the above-mentioned theory.

Whilst speaking of fibres unrolling spirally, I take the opportunity of showing a fact I have lately made out, that even membrane itself may occasionally be met with, that will tear and unroll spirally. Botanists

FIG. 87.



Hairs from the fruit of *Cycas revoluta* unrolling spirally.

generally describe membrane as tearing irregularly, but the hairs found on the outside of the fruit of *Cycas revoluta*, which are of some considerable size, will, when separated from the fruit, exhibit the appearance shown in Fig. 87; both extremities are pointed, but it is the one attached to the fruit that unrolls spirally.

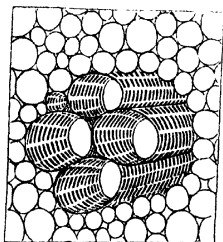
I shall next draw your attention to the variety of vessel which, from its peculiar markings somewhat resembling the rounds of a ladder, is called *Scalariform*; but this, like the other varieties, is but a modification and later stage of existence of the true spiral vessel, resulting from an unequal deposit of the secondary matter upon the inner surface of the cell-wall. The parts in which there have been no deposits, or, in other words, the pores, are always more or less elongated, like a slit, and have both extremities rounded. If one of these vessels, when divided vertically, be examined with a power of at least two hundred and fifty diameters, the depth of the pits may be distinctly seen.

These vessels present another peculiarity: they are often of hexagonal figure, and the markings, as well as the sides, are generally of uniform size, as shown in Fig. 88; in other cases, as in Fig. 89, both the sides and the markings are unequal.

The scalariform tissue is best seen in the root of *Ferns*, on tranverse sections of which, the naked eye discerns rows of black dots, with intervals of a lighter colour; the former are bundles of cellular and ligneous

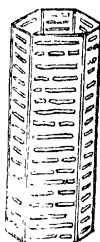
tissue, the latter the vascular tissue of the plant, which is almost entirely composed of scalariform vessels, arranged most frequently in a circular form. An

FIG. 88.



A bundle of scalariform vessels seen in a diagonal section of the root of *Pteris aquilina*.

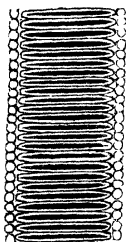
FIG. 89.



Scalariform vessel of hexagonal figure.

oblique section of the root of *Pteris Aquilina*, or *Common Brakes*, one of the most abundant of our *Ferns* (Fig. 88), exhibits the cut extremity of a bundle of

FIG. 90.



One side of a scalariform vessel from a *Tree Fern* of New Zealand.

these vessels lying among the ligneous tissue; the scalariform, or step-like markings of the walls, are well shown, and also the fact above mentioned, that they are not always circular in form, but often hexagonal or heptangular.

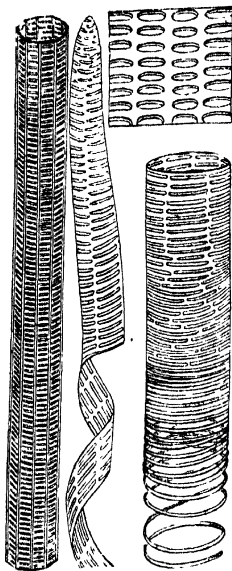
In Fig. 90, which represents a portion of a vessel found in a vertical section of a *Tree Fern* of New Zealand, these scalariform vessels are ex-

tremely large, being nearly double the size of those of the *Brakes* already described.

So characteristic are these vessels among the *Ferns*, that I have more than once identified our common *Pteris* from a small portion of its remains, especially in one instance, in which I found some fragments of a frond in a funereal urn. About two years since an urn, dug up in the island of Anglesey, was, with its contents, brought to me for examination by one of our most distinguished archæologists, Mr. Albert Way. After having determined the presence of human bones belonging to an adult, and to a child, probably a mother and her offspring, certain filaments were found adhering to the inner surface of the urn; these were of a brown colour, and arranged in definite order like the veins of leaves. Upon microscopically examining sections of these, scalariform vessels were noticed precisely similar to those occurring in the *Pteris*. This *Fern* is very abundant in the district in which the urn was discovered, and most probably, portions of fronds were placed in the receptacle before the ashes of the deceased persons were deposited in it.

As I have before remarked, the fact that these several varieties in the vascular tissue are dependent on modifications in the arrangement of the spiral fibre, is proved by the occasional occurrence of several of them in one length of vessel or duct; thus in a specimen from the *Pteris Aquilina* (Fig. 91, B) you will observe one vessel, which at its upper extremity

FIG. 91.



A, a portion of a scalariform vessel having nine sides. B, upper portion of a scalariform vessel unrolling in the form of a spiral band. C, middle portion of the same vessel unrolling like an ordinary spiral vessel. D, portion of a scalariform vessel magnified 500 diameters, showing the depth of the pits.

has the scalariform character; lower down, as shown by C, the markings are reticulated; still lower the original spiral form re-appears, and to this again succeeds a portion of ladder-like tissue. When stretched, as represented by the lower extremities of B and C, the scalariform vessels will unroll either in a band, or in single fibres.

I have on a previous occasion spoken of an exception to a general rule which occurs in *Ferns*, namely, that in them the membrane is frequently coloured brown, independently of its contents. When the colour is deep, the vessels collected into bundles, and arranged in a peculiar

form, are easily distinguished by the naked eye.

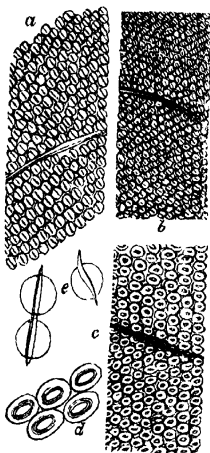
POROUS OR DOTTED DUCTS.

There are, in addition to the spiral vessels of which I have now spoken, other tubes or canals of large size, termed ducts, which give to woods their different degrees of porosity, and these are visible even to the naked eye. Some of them are marked by an internal deposit of fibre in addition to the pores, but unlike the spiral vessels, they are incapable of unrolling.

The usual markings exhibited are either simple or bordered pores. When these vessels are examined with a low power, the pores appear as dots, and hence the name "dotted ducts" has been given to them, the term "duct," being restricted to such vessels as are incapable of being unrolled.

In the *Cissampelos Pareira*, or *Pareira Brava*, the ducts form bundles, and are remarkable for the minute size of their pores; the extremity of each duct being more or less flattened. In

FIG. 92.



a b, portions of two porous vessels, or ducts, from the stem of a *Clematis*; *c*, portion of a porous duct from the *Alder*; *d*, pores of the same magnified 500 diameters; *e*, three bordered pores from a fossil wood.

a vertical section of the root of the *Alder*, the ducts as represented in Fig. 92, *c*, are of large size, and the bordered pores found on their walls, are also remarkable for the extent to which they are developed.

FIG. 93.



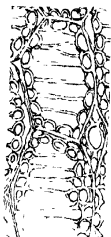
Porous vessel in
Anthracite coal.

In a section of anthracite coal, Fig. 93, the ducts are of great length, and all the pores are of an oval form. In the common *Clematis*, the ducts are of small size, but their termination by a septum or septa, situated nearly at an angle of 45° to the long axis of the duct is well shown in Fig. 92, *a, b*. Now, it often happens that these ducts, originally elongated cells, become continuous canals or vessels, by the absorption of the septa, but, in some cases, in which the process of absorption has either been incomplete, or fibres in the form of parallel bands, have been developed in the septa, these remaining at the edge of the septum, give this part of the duct a very peculiar appearance, somewhat like that of the bars of a gridiron.

In an oblique section of a foreign wood, given me by Dr. Robert Brown, porous ducts abound, and the fibres of the septa are well shown; they occur in parallel lines, like the bars of a gridiron, and, as represented in Fig. 94, the fibres join the walls of the pores at the margins of the ducts. In a section of a fossil *Palm*, from St. Vincent's, the extremities of the ducts are more or less conical, and the fibre is at these points

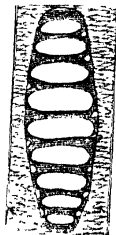
often developed into broad flattened bands, which are well represented in Fig. 95. One of the most striking examples of the gridiron tissue is to be met with

FIG. 94.



Termination of two porous ducts, the fibres of the septa being transverse and parallel.

FIG. 95.



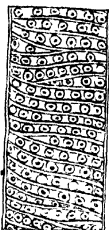
Termination of two ducts of a fossil *Palm*.

in vertical sections of the *White Birch*; in this tree almost all the vessels have septa composed of parallel fibres.

Peculiar forms of porous ducts are met with in the *Stigmaria*; they are frequently of great length, and in some specimens there is an appearance of the fibre between the pores of one duct passing across to join those of a neighbouring duct.

All the pores of the ducts I have hitherto mentioned have been either of the simple or bordered kind; but certain peculiarities occur in some plants which require notice. In the *Clematis*, represented by *a b*, in Fig. 92, an oblique line or marking passes through the centre of each pore; but in a specimen of fossil wood

FIG. 96.



Portion of a duct from the *Elm* showing pores and a spiral band.

from Herne Bay, as described by Mr. Bowerbank,* the markings shown on a large scale by Fig. 92, *e*, are double, and extend beyond the outer margin of the pore. In all these examples, the markings, as in the case of those of the woody tissue of *Cycas revoluta*, are produced by the elongation of the central portion of the pore.

In many porous ducts, and more particularly in those of the *Elm*, a spiral band co-exists with large bordered pores. A portion of a duct exhibiting this peculiar structure is represented in Fig. 96.

* "Transactions of the Microscopical Society," Vol. 1.

LECTURE IX.

CONCLUSION OF VEGETABLE TISSUES.

HAVING in my last Lecture completed the description of all the important tissues entering into the formation of vegetables, I shall now pass on to consider those composing the animal body ; but before doing so, I propose to take a rapid review of the subjects which have occupied our attention since the commencement of this course.

I stated in my first Lecture, that all plants were made up of an elementary membrane existing in the form of cells, each of which in the young state is provided with a nucleus or cytoblast and nucleoli ; the membrane being generally of a greenish colour, but, in *Ferns*, occasionally brown. The membrane in process of growth becomes thickened by secondary deposit ; this may be either in a homogeneous form, and occupy the whole

interior of the cell, or be deficient in certain parts, when pits or pores result, or it may occur in a spiral form, the general direction of which is from right to left.

I next called your attention to the various forms under which cells are found in plants, and explained, that in the young state and when unaltered by pressure, they are of a spherical figure, which becomes modified in process of growth into dodecahedrons, cubes, parallelograms, prisms, &c. &c., and even into fibres. I then passed on to the consideration of the contents of these cells, and gave examples of various colouring matters in a fluid state, which produce all the varied hues of the corollæ of flowers. I next noticed one of the most common of cell-contents, and the most useful to mankind, viz. : starch, which possesses definite and peculiar characters in different plants, and consists of granules of a more or less oval figure, composed of an outer membrane exhibiting a central spot or hilum and concentric lines, within which the amylaceous or starchy material is contained. I pointed out the relative sizes of the starch granules in *Rice*, *Potato*, and *Tous les mois*, and drew attention to the peculiar club-shaped bodies found in the milky juice of the *Euphorbiaceæ*.

Chlorophylle, a substance of a starchy nature, and the material that gives the green colour to all plants growing in the light, was next considered ; striking examples of it occur in the *Chara* and *Vallisneria*, in both of which plants the granules may be seen in active circulation within the vegetable cell. Other cell-con-

tents, such as milky juice, oil, resin, gum, were then mentioned, and separately described. Another product of cell-secretion is always found in a crystalline state, and known by the name of raphides. These are of various forms, sometimes occurring as single crystals, but more frequently in stellate masses of oxalate of lime in the *Rhubarb*, or in needle-shaped crystals of phosphate of lime in the *Squill*.

Another inorganic material, found principally combined with the tissue of the walls of cells, is silica, which I described as being so intimately blended with these tissues in certain plants, as to form a perfect cast of their original structure when all the soft vegetable matter has been removed; abundant examples of this being easily obtained from the *Grasses* and *Canes*.

I then exhibited a series of preparations in which sclerogen or hard tissue, approaching bone in many of its characteristics, occurred as a cell-content, but in no one case was a cell entirely occupied by it, a central cavity, with a system of radiating pores being always present. The last product of cells which I mentioned consisted of *Phytozoa*, or plant animals; these being found in the *Chara vulgaris*, in *Mosses*, *Ferns*, *Confervæ*, &c. Each cell of the antheridia of some *Mosses* is occupied by a spiral filament which exhibits a peculiar gyrating motion, precisely similar to that of the spermatozoa in animals, to which they are no doubt analogous.

The aggregation and modification of the cells previously described, make up the entire structure of all

classes, of plants, each variety being characterised by the name of *tissue*; thus we have the woody, the vascular, the porous, and other tissues. The first of these is the most important, since to it we are indebted for our linens, our cordage, and our paper. It consists of elongated tubes or fibres of a more or less cylindrical figure, and occurring in bundles; by maceration, and other processes, the fibres are detached from each other, and are then capable of being worked into fabrics of various kinds.

The vascular tissue consists of cells more or less elongated, joined end to end, or overlapping each other, in which either a spiral fibre or a modification of the same has been deposited; hence, if the spiral be perfect, such a vessel is called a *true spiral vessel*; if interrupted at certain parts, and the fibre breaks up into a series of rings, it is then called *annular*; if the fibre or rings be connected together by branching fibres, in such a manner that a network is produced, the vessel is called *reticulated*; if the fibres be nearly close together, and the vertical connecting bands short and equi-distant, the vessel is called *scalariform*, from the markings resembling the rounds of a ladder. Spiral vessels, from their resemblance to the air-tubes of insects, have been termed *Tracheæ* by some authors; the analogy, however, is not far fetched, as in both cases, the tubes are composed of a transparent membrane, kept open by a spiral fibre.

In all the above-described vessels the spiral fibre has

a tendency to unroll, but other cells, which are called porous ducts, are of great size, have their walls covered with large pores, and are not capable of being unrolled. These are the tubes visible to the naked eye in almost every wood. There are other ducts found in all plants yielding a milky juice, called laticiferous or milk vessels by Schultz, who, from supposing them to exhibit a circulation of their contents, likened them to the capillaries of animals ; but by recent examinations, both the existence of the circulation, and the entire continuity of the vessels, have been proved not to exist.

Such, then, is a brief outline of the subjects that have occupied our attention during the first part of the course. One great object which I have kept in view throughout, has been that of endeavouring to impress on you the fact, that each cell of a plant should be considered as having an independent or individual existence ; that in one situation it may secrete colouring matter, in another starch, gum, sugar, oil, &c. ; and in another the material for the reproduction of its species.

HISTOLOGY OF ANIMALS.

LECTURE X.

ANIMAL TISSUES.

I NOW proceed to consider the elementary tissues of animals, and see how far they correspond with those of vegetables. In their earliest condition the cells in both are nearly alike, in some cases the cellular character is maintained throughout life, but in others they rapidly undergo change of form, and all appearance of cell and nucleus is entirely lost. The animal cell, though in some degree possessing an independent existence, cannot perform its functions, as for example, that of secretion, without being in a certain relationship with a series of vessels carrying the nutritive fluid or blood. In the Animal as well as in the Vegetable Kingdom, we have membrane as an element ; it may

be met with in the walls of cells, but principally in the form of an investing membrane or sheath, in which case it is perfectly structureless and as transparent as glass. So far as I am aware of, no such extended membrane is found in vegetables unless cellular structure is visible. It is in this coalescence of cell-walls that animal structures principally differ from those of vegetables; in the latter the cell-wall is always present, however old or hard the tissue may be; but in the former, with the exception of those tissues termed cellular, it soon disappears, and in some cases, no trace is left either of nucleus or nucleolus.

It has been found very useful for the purpose of study, to arrange the elementary tissues of animals in a tabular form, and various have been the modes in which this has been carried out by different anatomists. One of the best of these tables, and that, which, with some slight alteration, has from the first been adopted in these Lectures, is given by Todd and Bowman in their "Physiological Anatomy." It would, however, be impossible to go through the entire series of tissues in one course of lectures; I have, therefore, thought it best to follow the order laid down in the above mentioned table, commencing with the simple tissues, and when there is occasion to allude to any one of the compound tissues, a short account of it will be given, in order that its relations to the subject under consideration may be the more readily understood.

TABULAR VIEW OF THE ANIMAL TISSUES.

1. Simple membrane: employed alone or in the formation of compound membranes	} EXAMPLES:—Walls of cells of the cornea. Capsule of lens. Sarcolemma of muscle, &c.	Posterior layer
2. Fibrous tissues		White and yellow fibrous tissues. Areolar tissue Elastic tissue.
3. Cellular tissues		Cartilage. Adipose tissue. Pigment. Grey nervous matter.
4. Sclerous or hard tissues		Rudimentary skeleton of Invertebrata. Bone. Teeth, &c.
5. Compound membranes composed of simple membrane, and a layer of cells of various forms, (epithellum or epidermis,) or of areolar tissue and epithellum		Mucous membrane Serous and synovial membranes. True or secreting glands.
6. Compound tissues. <i>a.</i> composed of tubes of homogeneous membrane containing a peculiar substance	} Muscle Nerve	
<i>b.</i> Composed of white fibrous tissues and cartilage		Fibro-cartilage.

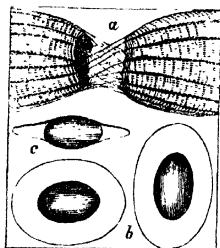
M E M B R A N E.

Membrane is thin, transparent, and structureless, it never presents any visible pores, although fluids pass through it readily; wherever it exists, it is more or less nourished by blood-vessels, which run on its outer surface, but never enter it. The posterior layer of the capsule of the lens of the eye of a *Sheep*, affords an excellent example of this elementary tissue, which is completely structureless, and as transparent as glass, having no trace of cell in or upon it, so that its very presence can only be discerned by accidental folds, or other irregularities. The capsule of the lens, especially its posterior layer, is in early life, very vascular, that is to say, vessels ramify freely on its surface, but they do not enter into its forma-

tion or structure. In the adult state, the vessels of the posterior capsule, if they do not altogether disappear, are rarely, if ever, capable of being injected; but in the *Snake*, the *Frog*, and some other reptiles, as will hereafter be shown, they are generally present.

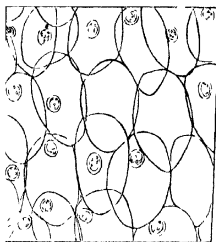
The same simple membrane forms a sheath for the minute elementary particles of muscle and nerve, being called in the former case, *sarcolemma*, by Bowman, and in the latter *neurilemma*, by Schwann. The *sarcolemma* is readily distinguished surrounding a portion of a fasciculus of muscle from an *Eel*, represented by *a* in Fig. 97. I have already said that

FIG. 97.



a, muscular fasciculus of an *Eel* showing the sarcolemma; *b*, blood corpuscles of *Lepidosiren annectens* magnified 500 diameters; *c*, one of the same seen edgeways.

FIG. 98.



Nucleated cartilage cells from the chorda dorsalis of a *Lamprey*.

simple membrane forms the walls of cells, as in the case of the blood corpuscles, which retain their original cellular character throughout life; those from the *Lepidosiren*, *Lepidosiren annectens*, Fig. 97, *b*, *c*, are

nucleated, of an oval figure, and with a single exception, are the largest known, being $\frac{1}{570}$ th in the long by $\frac{1}{940}$ th of an inch in the short diameter.

Other examples of elementary membrane occur in the early stages of cartilage, and in adipose tissue; of the former, a specimen (Fig. 98) from the *chorda dorsalis* of the *Lamprey*, bears a remarkable resemblance to the cellular tissue of plants; the nuclei, however, are sometimes wanting. In the cartilage from the ear of the *Mouse* (Fig. 99) the nuclei

FIG. 99.

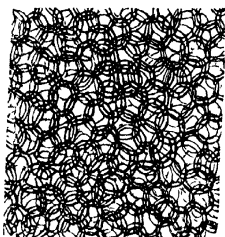
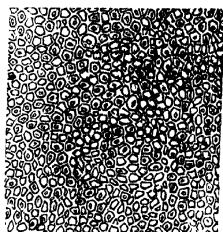
Cartilage from the ear of a *Mouse*.

FIG. 100.

Cartilage from the ear of a *Bat*.

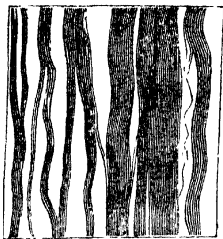
are absent, but in that from the ear of a *Bat*, *Plecotus auritus* (Fig. 100), they are generally present, each cell having a transparent nucleus in its centre.

FIBROUS TISSUE.

The fibrous, or filamentous form of tissue, enters largely into the construction of tendons, ligaments, fasciæ, and other analogous parts; it is of two kinds, called from their respective tints, white and yellow. Examples of white fibrous tissue are best obtained from tendinous structures, which are almost entirely composed of it. For the yellow, in an isolated condition, we resort to the *ligamenta subflava* of the human spine, or the *ligamentum nuchæ* of the lower animals. The tissue termed areolar, or the cellular tissue of the old anatomists, is composed of an intricate interlacement of the white and yellow fibres. The white fibres, which are most conspicuous in the natural state, may be made to disappear by the addition of acetic acid, so that the yellow fibres, which remain unaltered, can then be separately examined. The areolar tissue is more extensively diffused than any other throughout the animal body; it forms the connecting material between organs and tissues, and in some instances is found in such quantities in the *Elephant*, between the walls of the chest and the costal layer of the pleura, that it may be taken out by handfuls. The areolar tissue from the thorax of the *Elephant*, affords an excellent object for the exhibition of the nature and appearance of the white fibrous tissue, which occurs

either in white bands, composed of minute, equal-sized

FIG. 101.



Tendinous fibres from rectus muscle of the eye of an *Ox*.

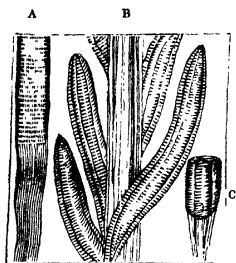
fibres, more or less wavy, or in separate fibres also wavy; these, however, may be rendered straight by extension.

In the tendons of the recti muscles of the eye of an *Ox*, this tissue is of silvery whiteness, and, as represented in Fig. 101, consists of flexuous fibres, all taking the same direction. In some parts, por-

tions of the same tissue are observed crossing the flexuous fibres, these are derived from the areolar tissue with which the tendon is invested.

Having explained and illustrated the nature and characters of white fibrous tissue in tendons, I shall digress somewhat, to describe the connexion of muscular fibre with tendons. This connexion is not effected, as has been generally supposed, by union with the investment or sheath of the muscle, but, as was first pointed out by Mr. Bowman, by a close connexion of the white fibres with the terminal disc of each fasciculus, as shown in a fibre from one of the recti muscles of the eye of a *Cat*, represented by A, in Fig. 102. The same mode of connexion is evident in the muscles of invertebrate animals,—as, for instance, in the common *Fly*. In most works on Entomology you will find that the brown, horny shaft B, with which the muscular fibres are

FIG. 102.



A, muscular fibre and tendon from rectus muscle of the eye of a *Cat*. B, muscle from the leg of a *Fly*. C, muscular fibre and tendon of a *Fly*.

connected, has been described as the tendon. If, however, the termination of any fasciculus be carefully examined, a perfect tendon of white fibres will be seen to spring from the terminal disc, and by this tendon, represented by c, in Fig. 102, the fasciculus is connected with the horny shaft. The tendinous fibres in some of the lower animals, as the *Mol-*

lusca, are of larger size than those in *Mammalia*. In the *Terebratula* they are remarkably large, nearly straight, more or less flattened, $\frac{1}{500}$ of an inch in breadth, and collected in strong bundles, which present to the naked eye a very beautiful silvery aspect. In birds the tendons, especially of the legs, are of large size and great strength, consisting of large bundles of white fibrous tissue, connected together by areolar tissue in which the blood-vessels run, as shown in a transverse section of one of the long tendons from the *Ostrich*. In some birds the tendons are more or less ossified; and all who may have been so unfortunate as to have been helped to the drumstick of a *Turkey* or *Goose*, must be familiar with the long tendons of these birds, which are flattened and tough near their muscular attachments, but bony near their insertions.

When a vertical section of a tendon of any large animal is examined, it always presents a silvery lustre, and the fibres, collected in bundles, proceed in parallel lines, each fasciculus being connected with its neighbour by areolar tissue. If a portion of tendon be dried, the greater part of the silvery lustre disappears, but when viewed by polarised light, not only is the direction of the bundles seen, but each displays a series of brilliant colours.

In the human body we have other structures besides tendons, which are composed almost entirely of white fibrous tissue; such are the periosteum, dura mater, &c. A peculiar form of fibrous tissue occurs in the *membrana putaminis* or membrane lining the interior of the shell of the egg of most birds and reptiles; it consists of several layers of fibres of nearly uniform diameter, which interlace with each other and produce a series of spaces or cells sufficiently large for gases to pass through. The fibres in an egg of the common *Fowl* are on an average $\frac{1}{8500}$ of an inch in diameter, and are not acted on by acetic acid. A thin layer of this membrane, having the fibres separated from each other, very much resembles the section of *Boletus igniarius*, represented in Fig. 18.

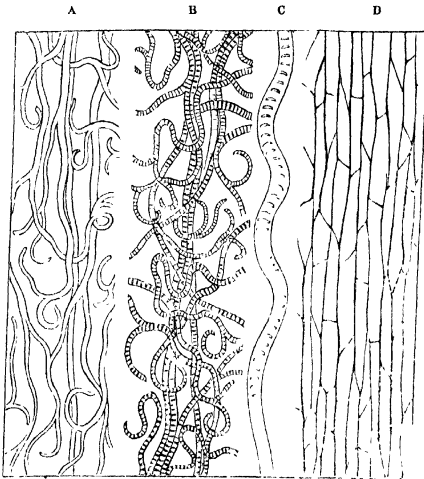
LECTURE XI.

YELLOW FIBROUS TISSUE.

THE yellow fibrous tissue differs considerably from the white, consisting of large more or less branched fibres, of a yellow colour, with curled extremities. It is found most abundantly, as I have already stated, in the ligamentum nuchæ of quadrupeds, and in the ligamenta subflava of the human spine. In the large *Pachydermata*, as the *Elephant* and *Rhinoceros*, it is frequently employed in the form of a belt or girdle, to support the abdominal parietes. In a specimen, from the ligamentum nuchæ of the *Sheep*, Fig. 103, A, the fibres are of large size and yellow colour, and much branched, their free extremities being more or less curled. In that from the ligamentum nuchæ of the *Giraffe*, Fig. 103, B, the same characteristic curled extremities are presented, but each fibre is marked with transverse striæ. When

examined with a power of 500 diameters, the striæ, as shown by c, do not extend across the entire diameter of the fibre, but appear to be principally confined to its centre. The ligament from which this specimen was taken was 6 feet 2 inches in length before it was

FIG. 103.



A, yellow elastic fibres from the ligamentum nuchæ of the *Sheep*. B, yellow fibres from the ligamentum nuchæ of the *Giraffe*. C, one of the same magnified 500 diameters. D, vessels of the ligamentum nuchæ of a young *Calf*.

separated from its attachments; when detached, however, it immediately contracted to 4 feet, or about one-third of its original length: it even now possesses some degree of elasticity, but the power must be enormous to stretch it even one foot. The weight of the entire

ligament was upwards of 8lbs, and the striped fibres are most abundant on the outer surface, the interior being occupied by plain fibres alone. The striped fibres are not confined to the *Giraffe*, I have lately seen them in the *Rhinoceros*, the *Sheep*, and even in arteries.

A modification of the yellow fibrous element constitutes the elastic coat of arteries; which is well shown in a fine specimen taken from the aorta of a *Whale* upwards of 50 feet in length; the diameter of the vessel is about 12 inches, and the thickness of the elastic coat $1\frac{1}{2}$ inch. When examined by the microscope, the fibres of arteries exhibit all the characters of those of ordinary elastic tissue, except that they are much more minute and less easy of separation.

Another variety of elastic tissue occurs in the ligament supporting the expanded wings of all our larger birds, such as the *Eagle*, *Crane*, *Heron*, &c. The ligament from the *Eagle* is quite as elastic as caoutchouc.

The last variety of this tissue which I shall notice, is that situated between the valves of *Conchiferous Mollusca*, in which it performs the office of opening the valves whenever the adductor muscle ceases to contract. In some shells, as the *Oyster*, this elastic substance is placed within the hinge, in others, as the *Cockle*, it is external to it; in the former, the expansive power of the compressed substance separates the valves, but in the latter, the same object is gained by the contraction of the hinge ligament. The structure of this form of

tissue has been fully described by my late brother, in the 1st vol. of the "Transactions of the Microscopical Society."

AREOLAR TISSUE.

We now pass on to a mixture of the white and yellow fibres forming a tissue most extensively diffused through the animal economy under the various names of cellular, fibro-cellular, and areolar tissue; the latter being the term now usually employed. The older anatomists imagined, that by the crossing and intertexture of the fibres, a series of more or less round or oval cells were formed; these spaces, however, have no distinct cell-walls, but are merely areolæ or meshes, the continuity of which is proved in cases of anasarca and emphysema, and by the inflation of this tissue with air by means of a blow-pipe.

The principal use of areolar tissue is that of connecting other tissues, and at the same time allowing greater or less freedom of motion between them. It forms, with few exceptions, the principal means of support to blood-vessels and nerves, accompanying both to their minutest subdivisions. It is largely developed in certain situations, as for instance, under the skin, where it has received the name of subcutaneous areolar tissue; under mucous and serous membranes where it is sometimes very abundant, and is then styled submucous or sub-

serous areolar tissue. In the mesentery of small animals, the *Rabbit* for instance, the subserous layer is represented only by a few branched fibres, these form a delicate framework over which the serous membrane with its epithelium is stretched. In all the situations, where it is normally found, it may be developed to such an extent as to form tumours, which when subcutaneous, often attain an enormous size. Most of those remarkable growths known as fibrous tumours, are composed of this tissue. They often occur in the neighbourhood of glandular organs, but specimens which have been described as fibrous tumours of the breast, are found on minute examination to be chiefly composed of hypertrophied glandular tissue, intermixed with only so much fibrous tissue as is sufficient to give support to the enlarged lobules of the gland.

When areolar tissue is examined with a power of two hundred and fifty diameters, it will be found, as

FIG. 104.

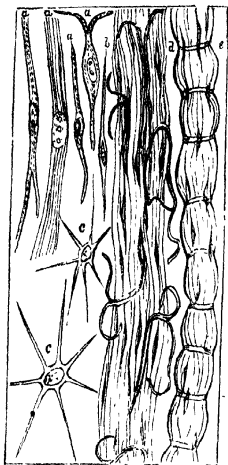


Areolar tissue of the *Elephant*:
aaa, white fibres; *bbb*, yellow
 elastic fibres.

before stated, to be composed principally of white fibres, the yellow or elastic element being only occasionally seen. In the areolar tissue from the pleura of the *Elephant* (Fig. 104) a few yellow fibres (*bb*) are visible, but when acetic acid is added to a portion of the same tissue, a remarkable change takes

place,—the greater part of the white fibres disappear, and nothing but long

FIG. 105.



a a b, fibre forming cells of areolar tissue; *c c*, stellate cells from a tumour in connection with the parotid gland; *d*, yellow elastic fibres seen in areolar tissue after the action of acetic acid; *e*, areolar tissue from the vessels at the base of the brain of a *Sheep*.

imperfect oval cells or nuclei remain; these, however, as shown by *d* in Fig. 105, indicate the direction previously occupied by the fibres. The yellow element undergoes no change when treated with the acid, and its fibres therefore stand boldly out, being as it were isolated from the surrounding white fibres, and exhibiting all the peculiar characters I have already described as belonging to this form of tissue. The yellow elastic tissue agrees in all points except in greater minuteness with that of the ligamentum nuchæ of the

Sheep. When areolar tissue is growing rapidly, as in tumours, the cells from which it is developed are often seen; some of the principal varieties are represented by *a b*, in Fig. 105, they are mostly of a fusiform figure, and what was once the cell-wall, in process of growth becomes a mass of fibres. In tumours connected with the parotid gland, I have more than once

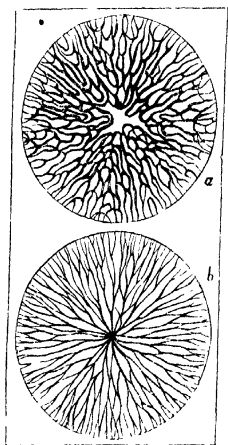
noticed that cells of the shape represented by *c c*, are very abundant.

A peculiar form of areolar tissue is found surrounding the vessels at the base of the brain of the human subject and some of the lower animals; when acted on by acetic acid, the white fibres, which are arranged in separate bundles, assume a tubular form, and the yellow element is seen surrounding them, either in the form of rings or spiral bands, a circumstance which has led some anatomists to suppose that these are blood-vessels in an early stage of formation. A specimen of this peculiar arrangement from the vessels at the base of the brain of a *Sheep* is represented by *e* in Fig. 105.

I now proceed to describe the mode in which simple membrane and fibrous tissues are supplied with blood-vessels, and the first example I shall take is that of the posterior layer of the capsule of the lens, which has already been described as a structureless membrane, nevertheless, it gives support to large blood-vessels derived from the *arteria centralis retinae*, which pass forward over the capsule as far as the iris, where they divide into two branches. These vessels can be readily injected in any young animal, but in the adult I have never yet succeeded in filling them, except in the case of certain reptiles, as for example, the *Frog*, *Toad*, *Newt*, *Common English Snake*, and *Tiger Boa*. In none of these animals do the vessels pass farther forwards than what may be termed the equator of the lens; they there

form a border composed of the largest vessels of the net-work, which are probably veins, joining those of the iris. Whilst on this subject, I will point out what I consider the true structure of the *membrana pupillaris*, which, as you are well aware, is generally looked upon as a distinct membrane closing the pupillary aperture, and when injected, differs from every other known membrane in the peculiarity of the arrangement of its blood-vessels. In three specimens of injected capsules of the lens in the Histological Series, the following peculiarities may be observed. In the first, the entire capsule is seen by the naked eye to be covered with

FIG. 106.



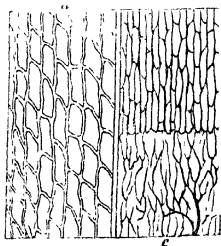
Vessels of the capsule of the lens of a *Puppy*: *a*, anterior layer of the capsule; *b*, posterior layer.

vessels, those on the posterior surface represented by *b*, in Fig. 106, being smaller than those on the anterior *a*; but when carefully examined with the microscope, the two sets will be found to communicate; those on the anterior surface *a*, are the so called vessels of the *membrana pupillaris*, and may readily be known by their forming a series of loops near the centre, but leaving that spot without any vessels. It therefore appears that at one stage of development of

the lens, the whole capsule is covered with vessels, and if it should so happen in the course of the dissection that the anterior layer be detached from the posterior, this anterior layer would be described as the *membrana pupillaris*; but if the lens come away entirely covered with vessels, no such membrane is found. The vessels from the posterior capsule, as before stated, when they reach the iris, divide into two sets of branches, one of which joins the vessels of the iris, the other those of the anterior capsule. These points are readily seen in specimens from the eye of the *Kitten*, *Wolf*, and *Puppy*, as well as in many other animals, which it is unnecessary here to mention.

We now proceed to describe the vessels of white fibrous tissue. The specimen represented by *a*, in Fig. 107, is a portion of the tendon of an *Ostrich*; the

FIG. 107.



a, vessels of the tendon of an *Ostrich*; *b c*, vessels of muscle and tendon of rectus externus of the *Ostrich*.

arrangement of its capillaries is very like that of muscle, the vessels are straight, and connected by branches more or less oblique; each vessel runs in the areolar tissue between the bundles, but never amongst the white fibres themselves. The number of the vessels in a tendon is very small as compared with those of the muscle to which

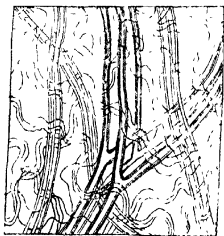
it is attached, and in all injected specimens as in the

Diaphragm, or in the *Rectus externus* muscle from the eye of an *Ostrich*, Fig. 107, the precise point where the muscle *b* ends and the tendon *c* begins, is readily perceptible even to the naked eye, not only by the diminished vascularity of the latter, but also by the difference in the arrangement of its vessels.

The vessels of the yellow fibrous tissue are few in number, and their arrangement, as shown by *D*, in Fig. 103, is somewhat similar to those of tendon; the connecting branches, however, are not transverse, but pass off at angles of about forty degrees, so that the spaces enclosed by the vessels have a somewhat diamond-shaped or rhomboidal outline.

The vessels of areolar tissue, on the contrary, are of small size and very numerous; they follow the direction of the principal fibres, and, as a general rule, form a coarse hexagonal network, which is filled up by capillaries or single vessels.

FIG. 108.



Vessels of areolar tissue from the neck of a young *Pig*.

This arrangement is represented by Fig. 108. As areolar tissue supports both blood-vessels and nerves, it often happens that the blood-vessels of the sheath of the former, or the neurilemma of the latter may be distinguished from those of the areolar tissue itself. In a specimen from the *Pig*, the vessels of

the neurilemma are plainly seen proceeding in a straight

line, and their arrangement is so characteristic to a practised eye, that the presence of a nerve may be asserted with confidence, notwithstanding all the nervous matter has been destroyed in the process of drying.

Although areolar tissue is the ordinary nidus in which the capillaries as well as the vascular trunks run in the various organs and tissues of the body, still there are certain situations in which the capillaries are wholly destitute of this means of support ; to these, the term *naked* has been applied by Professor Bowman. He first detected naked capillaries in the Malpighian bodies of the kidneys ; as the capillaries of the brain have no investment of areolar tissue, these also may be termed *naked*. I have discovered such capillaries in the interior of the glands of Peyer ; in a specimen from the *Dog*, the glands have been divided transversely, and capillaries may be noticed crossing and forming loops in the interior of the gland, but with no investment or support of areolar tissue ; the secreting cells usually found in these glands, in all probability, perform this office,

LECTURE XII.

CARTILAGE.

HAVING described the principal fibrous structures, I pass on to consider the cellular tissues ; of these, cartilage first claims our attention. This tissue possessing great elasticity and flexibility, enters largely into the formation of the vertebrate skeleton. It is usually white, or of a light grey colour, changing to a yellowish tinge after long immersion in spirit. Some animals, the cartilaginous fishes, for example, have a skeleton composed almost entirely of cartilage. In man, and the higher vertebrata, this tissue is employed more sparingly in the construction of the adult skeleton ; but in the foetal state the form of the skeleton is sketched out in cartilage, which in the process of development is entirely converted into bone.

Cartilage is usually divided into two kinds, the per-

manent and the temporary. The first, or permanent variety is employed, as before stated, to supply the place of bone, in the skeleton of cartilaginous fishes; or in the form of a membrane, either as tubes enclosing cavities, when it is called *membraniform*, or as a coating to the ends of bones, entering into the formation of joints, when it is termed *articular*. The second, or temporary form, includes the cartilage of the young of vertebrate animals, as well as all other kinds, which, in process of growth, are converted into bone. All these varieties of cartilage, except the articular, are covered with a strong layer of fibrous tissue termed *perichondrium*, which being analogous to the periosteum of bone, serves as a support to the blood-vessels and nerves.

The simplest form of cartilage, when examined microscopically, is found to resemble the cellular tissue of vegetables. It consists of a series of cells of a spherical or hexagonal shape, capable, in some cases, of being separated from each other, each of which as previously shown in Fig. 98, possesses a nucleus. In this condition, it forms the *Chorda dorsalis* or rudimentary spinal column of the *Lamprey*, and of the tadpoles of the *Toad* and *Frog*.

In the form of a firm membrane, it is employed in the construction of the framework of the ears of small mammalian animals, such as the *Bat*, *Mouse*, and *Rat*. In the *Bat*, especially the long-eared English variety, *Plecotus auritus*, the cartilage consists of a series of hexagonal cells, on an average $\frac{1}{800}$ th of an inch in

diameter. At the edges of the ear, the cells are in a single layer, but in the thicker parts two or more layers are superimposed. In these situations the cartilage is precisely similar to certain forms of vegetable cellular tissue.

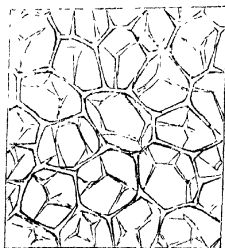
The ear of the common *Mouse* may be taken as a good specimen of simple cartilage; the central portion consists of a series of hexagonal cells arranged in layers one over the other, so that in every other respect, except in the size of the cells, the structure resembles that of a transverse section of the pith of a plant; this, however, has been before alluded to, and represented in Fig. 99.

In the thin cartilage of the ear of the *Bat* above named, the cartilage cells are of smaller size, and have thicker walls than those of the *Mouse*; in all parts, especially on the edges, the cartilage is sufficiently transparent to be seen through; and, in nearly every cell, as central nucleus may be observed. This, like the pre-

ceding, has been before described, and is represented in Fig. 100.

The transverse section of the *Chorda dorsalis* of a *Lamprey*, a portion of which is represented in Fig. 109, consists entirely of large cells of a more or less hexagonal figure, those near the margins

FIG. 109.

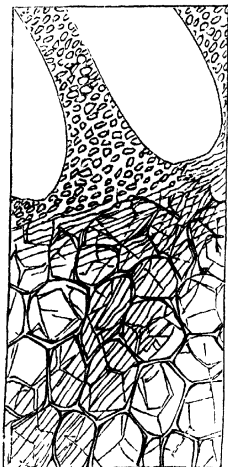


Transverse section of the *Chorda dorsalis* of a *Lamprey*.

being arranged in the form of radii. Some parts of this *Chorda dorsalis*, especially those near the centre,

FIG. 110.

A



Portion of the vertebral column of a *Trout* three weeks old: A, part of a spine composed of transitional cartilage. B, *Chorda dorsalis*.

are soft and pulpy; in these, the cells can be separated from each other, but, nearer the circumference, the cells are more compressed and very firmly adherent.

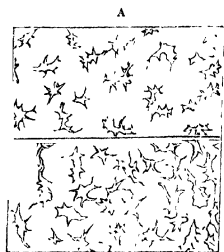
These large cells are not confined to the *Chorda dorsalis* of cartilaginous fishes, they exist also in the embryos of osseous fishes, and in the *Tadpoles* of batrachians. A portion of the vertebral column of a *Trout* three weeks old is represented in Fig. 110; the larger cells seen at B constitute the true *Chorda dorsalis*, which never becomes ossified; but above them, as

at A, a rudimentary neural spine is seen, this is composed of cells of much smaller size, and characteristic of cartilage that is afterwards converted into bone. At this early stage, then, we can distinguish between permanent and transitional cartilage.

In the examples I have hitherto given, no other substance than the cells has been alluded to; the majority of cartilages, however, will be found to consist of a matrix

in which the cells are imbedded. The matrix may either be perfectly homogeneous in structure, or granular, and it is not unfrequently fibrous ; to this substance I would

FIG. 111.



A, cartilage of the Cuttle-fish, *Sepia officinalis*. B, portion of an *Enchondroma*.

give the name of intercellular substance or matrix. The lowest animal in which I have been able to meet with cartilage is the *Cuttle-fish*. In this cephalopod it occurs in the form of a rudimentary skeleton ; the cells (Fig. 111, A) are small, more or less irregular in figure, like the cells of bone ; and are imbedded in a

structureless intercellular substance. Around some of these cells there is a faint trace of cell-wall, and it becomes a question whether many of them should not be considered as altered nuclei.

Cartilage is sometimes found in large masses, as a product of disease, in the form of tumours, termed *Enchondroma* by Müller. These tumours may be formed in connexion with any of the bones, but are more frequently attached to the phalanges, and the bones of the extremities. They are made up of cells like those of cartilage, but occasionally they also contain cells of a very peculiar form, Fig. 111, B, bearing a striking resemblance to the lacunæ of bones, but more especially to the cells found in the cartilage of the *Cuttle-fish*, above mentioned ; to these tumours I shall

have occasion to revert in a future Lecture. In cartilaginous fishes generally, all parts of the skeleton, except the *Chorda dorsalis*, are composed of a firm hyaline intercellular substance, in which, numerous oval nucleated cells are imbedded, they are generally arranged in groups of five or six; distinctly nucleated cells exist in the cartilage of the head of a *Ray*, which also occur in fasciculi or groups imbedded in a slightly granular matrix. In another section of the cartilage from the same *Ray*, the granular appearance is more evident; this portion of the cartilage, which will be alluded to hereafter, is undergoing the process of ossification, and the granules are those of osseous matter.

In *Reptiles*, the cartilage-cells are larger than in *Fishes*, and in the *Siren* they attain their greatest size; they are smallest in the *Crocodylia*. In *Birds* there is scarcely any cartilage, except that entering into the formation of the joints; in these animals all the cartilage is converted into bone, at a very early period of life.

In the *Mammalia* we have large cells, and a firm structureless intercellular substance; the largest cells, according to my own observations, being those in the *Elephant*. In some cases, the intercellular substance is of a fibrous character; if thin sections be taken from the cartilage of the ear of the *Rabbit* or *Dog*, the cells can be detached from the meshes formed by the fibres. In a vertical section of the cartilage of the auricle of the human ear, the cells are in some parts

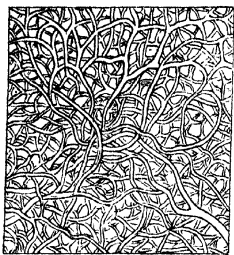
uniform in size, and closely packed; in others, the intercellular substance is fibrous, and occasionally some of the cells, as I have just mentioned when speaking of the ear of the *Rabbit*, can be separated from the fibrous net-work surrounding them. The reverse is the case in sections of the costal cartilage of the human subject, in which the cells are few, and widely scattered, whilst the matrix is most abundant; the cells are of large size, and frequently arranged in rows, their nuclei are clear and transparent, and the matrix minutely granular.

I now proceed to describe the mode in which this permanent form of cartilage is supplied with blood. Cartilage, as I have already stated, is invested with a fine glistening membrane called *perichondrium*, which supports the vessels and is prolonged with them into the interior of all the thicker cartilages; the distribution of the vessels is very like that in areolar tissue.

In an injected specimen of cartilage from the ear of the *Rabbit*, the vessels are of large size, and each artery is accompanied by two veins, many of which are perceptible to the naked eye, but the vessels are by no means numerous.

On the cartilage of the auricle of the human ear, I have observed that the vessels of the outer surface are more numerous and larger than on the inner surface. On the former, the vessels are exceedingly large and tortuous, (Fig. 112), and their arrangement is manifestly different from those of areolar tissue. On

FIG. 112.



Vessels of auricle of the human
Ear.

the latter, the vessels have the same arrangement, but it may be readily seen that they are smaller and much less numerous. This description applies only to the most vascular portions of the cartilage, for in those parts which have a less amount of vascularity, the arrangement of the vessels is precisely that of areolar tissue.

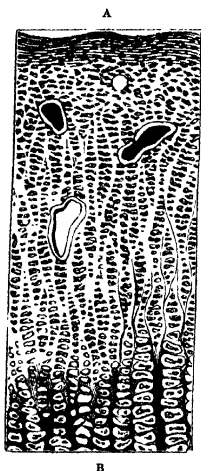
LECTURE XIII.

ARTICULAR CARTILAGE.

HAVING now described to you the principal forms of membraniform and permanent cartilage. I pass on to notice that variety of permanent cartilage, which, from its entering into the formation of joints, is called *Articular*. It differs in structure in the young and in the adult animal, and it is this form of cartilage which, in the young condition is largely supplied with blood-vessels, and undergoes a constant and successive process of ossification, on its attached surface. If a vertical section of foetal cartilage be examined, the part nearest the articular surface (Fig. 113, A) exhibits numerous small cartilage-cells, arranged without much order, and the nucleus of each cell occupying its whole diameter. As we proceed towards the attached surface, the cartilage-cells begin to be arranged in parallel rows,

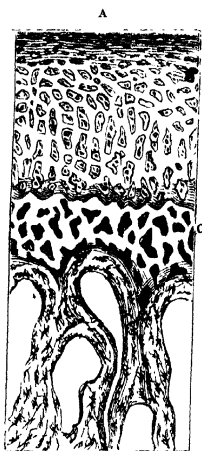
and the distance between the nucleus and cell-wall becomes much greater; and last of all, close to the attached surface B, we find spicula or lines, projecting between the parallel rows of cells; these are sections

FIG. 113.



Vertical section of articular cartilage from the head of the humerus of a foetal *Wolf*: A, articular surface. B, attached surface.

FIG. 114.



Vertical section of articular cartilage from a human metacarpal bone: A, articular surface. B, bone of the shaft. C, articular lamella.

of the walls of tubes of newly-formed bone, and which, when fully developed, become solid, each having enclosed a column of large cartilage-cells. In many sections of articular cartilage, as in Fig. 113, A, taken from the head of the humerus of a young *Wolf*, there are foramina through which blood-vessels pass to nourish

it, these are indicated by the four oval spots or holes, two of which are shown as being filled with injection.

In adult Mammalian articular cartilage, represented by Fig. 114, the arrangement of the cells is very peculiar; the cartilage is separated from the bone by a white layer (c) of variable thickness, and which contains bone-cells three or four times as large as those of ordinary bone. This is the non-vascular lamella first described by Mr. Toynebee, the lower portion is connected with the osseous tissue of the shaft of the bone (B), while the upper is more or less tuberculated for the attachment of the cartilage. The cells in the lowest layer of cartilage, or those immediately above the lamella, are arranged in columns parallel to the axis of the shaft of the bone, but as we proceed to the articular surface, the columns become smaller, more numerous, and their direction is changed, so that they are now at right angles to the axis of the shaft. Immediately on the articular edge of the section (A), the cells are so much flattened as to present the appearance of epithelium cells, and the intercellular substance or matrix of the cartilage, assumes a fibrous appearance. Adult articular cartilage is not vascular; the capillaries of the osseous tissue of the shaft of the bone terminating in loops as they approach the non-vascular lamella. From this brief outline of the structure of articular cartilage in the young and adult condition, I proceed to notice some peculiarities in that of fishes, reptiles, and birds.

In fishes, as in the vertical section of the jaw of a *Conger eel*, the cartilage-cells are small in size, very few in number, and arranged without much order in a distinctly fibrous matrix, the fibres of which follow the direction of the shaft of the bone. Upon the articular surface, however, the cartilage-cells are minute, and arranged in parallel rows; but they are so abundant as to obscure all trace of fibres.

In reptiles, as in the *Tortoise*, the articular or free surface of the cartilage has a distinctly fibro-cartilaginous structure; the fibres interlace and produce meshes, in which the cartilage-cells are lodged. Near the bone the fibres disappear, and the cells are of an oval shape, and few in number. The most remarkable circumstance in connection with this specimen is the great thickness of the fibro-cartilage of the articular surface.

In the *Batrachia*, as may be observed in a section of the head of the femur of a *Frog*, the cartilaginous matrix is clear and transparent; the cartilage-cells are smallest and most numerous in the part nearest the bone, but as we proceed towards the articular surface they become larger, and the nuclei are more plainly seen. The most interesting fact connected with the cartilage of the *Batrachia* is, the large size and uniformity of arrangement of the cells upon the articular surface; they are perfectly flat, resemble scales of tessellated epithelium, and many of them exhibit an appearance of one large cell dividing into four by cruciform fissures at right angles to each other.

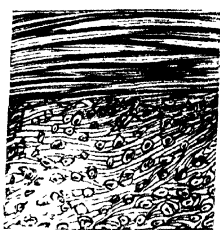
In birds, the articular cartilage is always more or less fibro-cartilaginous. In the *Turkey*, the fibres proceed in straight lines in the direction of the shaft, the cartilage cells being arranged in rows between the fasciculi of fibres. The articular surface of the specimen Fig. 115, exhibits fibres running in various directions among the cartilage-cells; this arrangement is constant in birds, and is precisely similar to that occurring in fishes. It is a remarkable fact, that in birds there is little or no cartilage except that of the

FIG. 115.



Articular surface of cartilage of the
femur of a *Turkey*.

FIG. 116.



Vertical section of articular cartilage
of the femur of a *Turkey*.

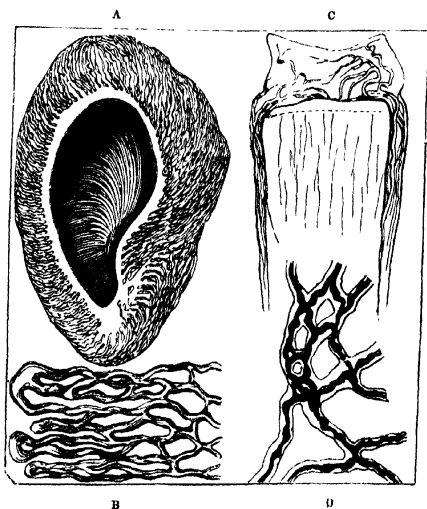
articular surfaces of the joints, and occasionally the rings of the trachea; all the parts of the skeleton of these animals are rapidly converted into bone, and even in the joints, the coating tissue, Fig. 116, often of considerable thickness, is composed of fibro-cartilage.

The moment, however, we examine sections of articular cartilages in the Mammalia, we find a constant arrangement of the cells, and in the adult

the non-vascular lamella makes its appearance. In the part of the cartilage nearest the articular lamella, as seen in a section of the articular surface of the bone of an *Ox*, the cells are arranged in columns, but near the articular surface their direction is changed. The same thing is evident in vertical sections of the articular cartilage of the humerus of a *Pig*, in which also, a well-developed non-vascular lamella is visible, and as in the *Ox* the cartilage-cells near the articular surface are arranged at right angles to those nearest the bone. In a vertical section of the head of a femur of a female, aged nineteen, the same arrangement is perceptible; but it will be noticed, that the articular lamella is sparingly developed. In a vertical section of the corresponding bone of a female upwards of seventy years of age, in which the arrangement of the cells in the cartilage precisely resembles that in the preceding case, the non-vascular lamella is nearly twice as broad. If the free surface of the articular cartilage of the young woman be examined, the cells will be seen to be more or less flattened, and to contain nuclei; in the older woman the cells are present, but the nuclei have disappeared. Having demonstrated the principal varieties of articular cartilage, it now becomes necessary that I should speak of the synovial membrane, which is said by some persons to invest the whole articular surface. In the foetal condition of man and of the higher mammalia each joint is covered with synovial membrane and an epithelium; as soon, however, as the joint is used, the

epithelium, and subsequently the synovial membrane itself disappears from all parts subjected to friction, although, as Mr. Toynbee remarks, it is sometimes persistent on the patella. In all my observations on the synovial membrane, and in the sections made for description in the Histological Catalogue, which include specimens taken from a large number of animals of each of the four great classes, I have never found it very far in advance of the vessels.

FIG. 117.



Vessels of synovial membrane and articular cartilage: A, glenoid cavity of human fœtus. B, looped vessels of the synovial membrane. C, vertical section of radius of human fœtus. D, vessels of fœtal articular cartilage running in canals.

Articular cartilage in the foetal condition is supplied with blood-vessels, which pass into its substance, and all parts in the neighbourhood of its articular surface are nourished by the vessels of the synovial membrane, which, as will be presently shown, always terminate in looped extremities immediately on the margin of the surface subjected to pressure. The glenoid cavity of a human foetus, Fig. 117, A, is surrounded by a margin of capillaries which project inwards as far as the socket for the reception of the head of the humerus, where each terminates in a looped extremity, the loop itself, Fig. 117, B, being sometimes dilated to two or three times the size of that of the vessel from which it is derived, it would seem that the synovial fluid is poured out from these dilated vascular loops. In a vertical section of the head of a metacarpal bone of an adult, the looped vessels of the synovial membrane are distinctly seen passing upon the articular cartilage as far as the part subjected to friction; these vessels do not enter the cartilage, neither is there any other source from which adult cartilage can derive its nutrition, except these vessels of the synovial membrane

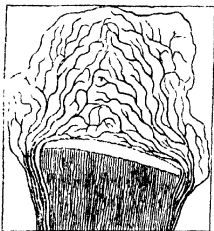
LECTURE XIV.

ARTICULAR CARTILAGE.—SYNOVIAL MEMBRANE.

HAVING demonstrated that the vessels of synovial membrane, both in the fœtus and in the adult, pass upon the surface of articular cartilage as far as the part subjected to friction, I will now endeavour to point out in what way the interior of the cartilage is supplied with vessels, and I shall in the first place describe a vertical section of the upper half of the right radius of a fœtus, Fig. 117, c, in which, vessels from the periosteum may be seen passing into the cartilage immediately above its connexion with the shaft, these divide and subdivide into numerous branches. The shaft of the bone also is injected, but its vessels are not continued into the cartilage, the layer of bone upon which the cartilage is situated, termed by Mr. Toynbee the non-

vascular lamella, and indicated by the dotted line, not admitting of their passage through it. The vessels of the shaft on reaching the lamella are said to terminate in loops. In the opposite half of the same specimen, which is represented in the Histological Catalogue, Plate VIII, Fig. 4, it may be seen, even with the naked eye, that the shaft in the immediate vicinity of the cartilage has a greater number of vessels than any other part, and it is at this spot that the growth of new bone is taking place. Immediately above these vessels the cartilaginous epiphysis is seen, and upon all parts of its surface, except those subjected to friction, the capillaries of the synovial membrane are distributed, all of them terminating in loops. In a vertical section of the head

FIG. 118.



Vertical section of the head of a tibia of a human fœtus.

of a foetal tibia with its epiphysis attached, a rich network of vessels belonging to the synovial membrane ramifies upon its upper margin; there are numerous vessels also in the epiphysis, some of which enter the cartilage near the upper margin, but others, as shown in Fig. 118, may be seen winding round between the upper part of the shaft and the epiphysis; these last are derived from the articular vessels of the periosteum.

In the shaft, Haversian canals may be observed, some of these have vessels in them. The portion of bone

immediately beneath the epiphysis is whiter than the rest; this is the non-vascular lamella before alluded to, and no vessels pass through it to supply the cartilage.

All the vessels of foetal cartilage run in canals. In the early stage of embryonic existence, as Mr. Toynbee has demonstrated, the cartilage has deep notches or indentations for their reception, and at a later period of growth the canals are still visible in the interior. In a section from the head of the humerus of a human foetus, the vessels, Fig. 117, D, are very numerous and irregular in their outline. If any one of them be accurately focussed, it will be seen enclosed in a tube or canal. The vessels themselves are small in comparison with the canal in which they run, but other vessels may be noticed in the neighbourhood, which are so distended as to fill the entire canal.

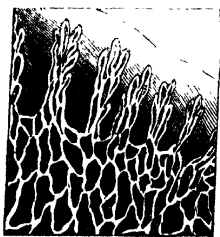
In healthy adult articular cartilage, there are no vessels; but in morbid conditions of the same tissue, vessels occasionally become more or less numerous. The latest period of life at which I have discovered vessels in healthy cartilage is twelve years.

In the specimen before represented in Fig. 114, A, which is a vertical section of the head of a metacarpal bone of an adult, the vessels of the shaft of the bone could be traced until they reached the yellowish band, or the non-vascular, or articular lamella, and here they ended in loops. The cartilage in this specimen is distinguished from the lamella by being whiter and much more transparent. The lamella is even present

in the foetus, it is indicated by the dotted line in Fig. 117, c; the vessels of the cartilage, which in this instance are very numerous, being derived from those of the articulation, and not from those of the shaft.

The non-vascular character of healthy articular cartilage, is maintained from the period of youth to old age; but, if disease occur, vessels may soon be found in it. In a specimen from a diseased joint, which after removal was carefully injected, numerous vessels may be observed passing through the cartilage; they are derived from the vessels of the shaft, as the articular lamella being involved in the disease, permits the vessels to pass through it; they proceed in straight lines through the cartilage to the free articular surface upon which they form a network, and anastomose with others probably derived from the synovial membrane. The subject from whom this specimen of cartilage was obtained was fifty years of age, and the disease had existed for nearly twelve months.

FIG. 119.



Section of diseased articular cartilage largely supplied with vessels.

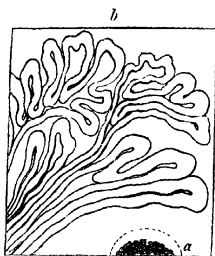
A preparation which belonged to the late Mr. Liston, and which he was in the habit of exhibiting in his Lectures, consists of the head of the tibia, with diseased cartilage attached. Not only can vessels be seen by the naked eye, passing from the bony shaft into the cartilage, in the form of loops, as in Fig. 119, but a

rich net-work may in some cases be observed upon a large portion of the articular surface. As far as I have been able to learn from examinations of diseased articular cartilages, especially those affected with ulceration, I conclude that the change first takes place in the cartilage cells, as is made evident by their becoming rounder and much larger in size, and by their contents assuming a different character, the nuclei disappearing, and globules of oil taking their place. In some cases these oil-globules are of very minute size, and the cells then appear granular; as the disease goes on, the cell-walls are absorbed, a series of cavities are formed, all the hyaline substance in the neighbourhood becomes more or less fibrous, and ultimately blood-vessels are developed in the fibrous tissue. The diseases of cartilage have been studied by very many able observers, especially Sir Benjamin Brodie, the late Mr. Key, Mr. Liston, and more recently by Dr. Redfern, of Aberdeen, whose papers will be found in the "Monthly Journal of Medical Science," for 1849.

The nutriment of articular cartilage is derived from two sources, namely, the articular vessels and those of the synovial membrane, more especially the latter; but neither set ever enters its substance, the one set ending in loops immediately without the parts subjected to friction in the movement of the joint, the other set confined to the cancelli of the shaft of the bone, and separated from the cartilage by the non-vascular lamella. The vessels of the synovial membrane of foetal articular

cartilages have been already noticed. In the adult condition, as shown in a portion of the head of a metacarpal bone, Fig. 120, *a*, the vessels are equally numerous, and

FIG. 120.



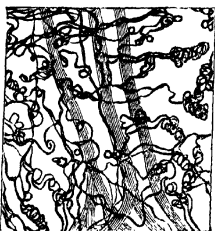
Vessels of synovial membrane: *a*, portion of the head of a metacarpal bone of an adult with the synovial vessels injected; *b*, vessels from a part of the same magnified 20 diameters.

when magnified at least twenty diameters, their looped terminations *b* are well displayed; they not only are continued upon the cartilage as far as the parts concerned in locomotion, but in some cases processes of the membrane, like fringes or large villi, richly supplied with vessels, project into every nook and corner where they

are not liable to injury. These processes, which in the knee-joint were described by Clopton Havers, and stated by him to possess a glandular office, have upon more recent investigation been presumed to be entitled to such a character as Havers ascribed to them, although most anatomists since his time have regarded them as masses of fat. If one of the joints of a finger be laid open, the vessels of the synovial membrane forming the capsule of the joint will be found thrown into a series of processes like villi, which are largely supplied with vessels remarkable for their tortuosity. These villi project into all parts of the cavity of the joint, and the vessels are supposed to pour out the synovia; they may, therefore, be viewed as synovial glands. The

arrangement of the capillaries of some of the largest specimens is represented in Fig. 122, *a*; similar processes, which no doubt secrete a fluid somewhat like synovia, are found within the sheaths of tendons, and upon those tendons which perforate or are perforated by others, as in the case of the flexor tendons of the fingers. Every part of the surface, both of the tendon and of the sheath in which it is contained, has a rich capillary network, except in such parts as are subjected to friction. The vessels of the synovial sheath (Fig. 121)

FIG. 121.

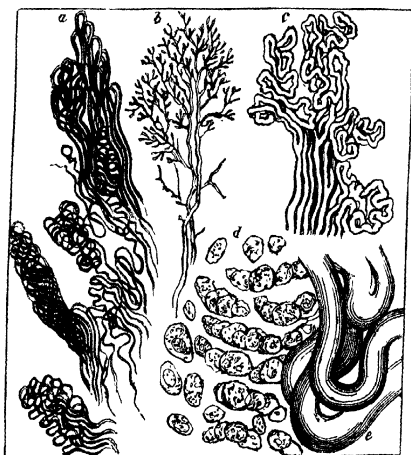


Tortuous vessels from sheath of flexor tendon of the middle finger.

are remarkable for the manner in which they are convoluted into a somewhat heliacal form, but the helices do not project far beyond the general surface of the synovial membrane. In another specimen, of larger size than the preceding, and which has been dried after injection, the capillary network and the helices are beautifully shown, and still nearer the joint the vessels are more numerous. If a portion of this vascular membrane be removed and carefully examined with a power of two hundred and fifty diameters, the capillaries will be generally found to terminate in loops, but the synovial membrane itself extends some little distance beyond the vessels, in a few cases as far as $\frac{1}{25}$ th of an inch; this non-

vascular portion being covered with epithelium. One of the villi, with its looped vessels, is represented in Fig. 122, *c*, and a few of the loops more highly magnified in Fig. 122, *e*; the scales of epithelium upon the basement membrane extending beyond the vessels are shown at *d*.

FIG. 122.



Vessels of synovial membrane: *a*, villi from joint of middle finger; *b*, looped vessels from flexor tendon of leg of an *Ostrich*; *c*, villus from head of metacarpal bone; *d*, epithelium of synovial membrane in advance of the vessels; *e*, loops of synovial vessels magnified 500 diameters.

Whilst on the subject of synovial vessels, I will take the opportunity of demonstrating those accompanying the ligamentum teres from its origin to its insertion; and it may not be out of place here to mention the fact, that some few animals, as the

Elephant, have no ligamentum teres; in the *Frog* there is no ligamentum teres in the hips, but one in the shoulder-joint; the use of the ligament in this situation being explicable by the habits of the *Frog*, that of hopping and pitching principally on its fore-feet, whereby a considerable tendency to dislocation must necessarily occur in the shoulder-joint. If the ligament be examined in a well injected foetus, a large supply of blood-vessels will be found in the synovial membrane of the acetabulum which proceed in straight lines along the ligament, and terminate in loops close to its insertion into the head of the femur. A preparation illustrative of this fact is accurately represented in Plate VIII., Fig. 9, of the "Histological Catalogue," but the looped termination of the capillaries is best seen in Fig. 8, this being a more highly magnified view of that part of the femur into which the ligament is inserted.

The vessels of synovial membrane, and those of the sheaths of tendons, have been well described by Mr. Toynbee and Mr. Rainey, especially by the former gentleman, who has figured those of the ligamentum teres in a paper published in the "Philosophical Transactions" for 1841. The beautiful looped vessels are not confined to the human subject, but exist in most of the lower animals. In the long flexor tendons of the leg of an *Ostrich*, circular patches of capillaries may be seen, each of which, as shown in Fig. 122, *b*, terminates in a dilated loop. The vessels of tendon which were exhibited when describing the vascularity of fibrous structures, were

those of the *Ostrich*, and it was then mentioned that the rich superficial network belonged to the sheath of the tendon, and not to the tendinous fibres themselves.

Whilst treating of articular cartilage, I may mention a peculiar deposit, as it is termed, which takes place in many joints that have been deprived of their cartilage by disease. The parts subjected to friction, in the movements of the joint, present a highly polished appearance, which is known as the *ivory-like* or *porcellaneous* deposit. If these specimens be examined, it will be found that all parts of the bone in the neighbourhood of the joint have an additional quantity of bony matter thrown out probably as the result of rheumatic inflammation. The same thing, no doubt, would have taken place upon the polished surfaces, had not the exuberant growth been kept down by the friction; and, as no bone occupying this situation, unless of preternatural hardness, could receive such a polish, I was led to speculate on the cause of the appearance. I therefore removed slices, and rendered them sufficiently thin for microscopic observation, by grinding away the cut surface; and, having examined them, I found that there was an almost total absence of the Haversian canals, whereby the bone was rendered exceedingly dense, and I concluded that the new osseous matter, having been prevented by friction from being thrown out upon the surface, was employed in filling up the canals, and by this means a substance, originally porous,

was converted into a solid mass, susceptible of taking the highest polish. This view of the subject corresponds precisely with a practice adopted by French polishers, who are occasionally obliged to fill up the pores, or canals, in many of the hard woods, such as rosewood and mahogany, before they can bring the polish to any perfection. I must now allude to a point which, for many years, has been the subject of dispute among anatomists, namely, whether the synovial membrane is continued over the surface of articular cartilage. If a joint from a very young animal be examined before it has been used, the surface of the cartilage will be found covered with synovial membrane, having an epithelium of that variety known as the tessellated; within a short period, however, after the joint has been used, the epithelium disappears, and, subsequently, the synovial membrane itself. This view of the subject is the one generally entertained; but Mr. Toynbee is of opinion that the membrane is not unfrequently present upon the cartilage, although its epithelial coating may have disappeared. In making the preparations described in the Histological Catalogue, many hundred sections were taken from the cartilages of the four great classes of animals; all were examined with reference to this point, and I have satisfied myself that the membrane is rarely, if ever, continued over the cartilages of the long bones of the adult. In the patella, and other sesamoid bones, the synovial membrane, as shown by Mr. Toynbee, may occasionally be

stripped off, but not from the surfaces of the more perfect joints. All my examinations tend to prove that the synovial membrane is continued a short distance beyond the vascular network, and that it ends at the point where friction commences. The cells on the surface of the cartilage, which have so frequently been mistaken for those of epithelium, are nothing more than ordinary cartilage-cells very much flattened; the resemblance of these cells to epithelium is most strikingly shown, as I have already stated, in the *Batrachian* reptiles.

LECTURE XV.

CARTILAGE. — ENCHONDROMA.

WE now arrive at the examination of a structure presenting all the characters of cartilage, which occurs in the form of tumours, and named by Müller *Enchondroma*. Tumours of this character may occur in many situations, and sometimes attain a considerable size. One removed from the neck of a man, by John Hunter, weighing one hundred and forty-four ounces, and consisting of nodular masses of cartilaginous texture, bound together by areolar tissue, is preserved in the Museum of the College. Another specimen, in the same collection, is that of a hand amputated by Sir Astley Cooper, which has enchondromatous tumours attached to almost every bone. A tumour of this kind removed from the cheek by Sir W. Blizard, forming Prep. 202, in the Pathological Series, contains numerous spicula of bone.

The leg of a young woman having a tumour also of this character, twenty inches in circumference, was lately removed by Mr. Lloyd at St. Bartholomew's Hospital. If these tumours are carefully examined, they will be found to be composed of a tissue resembling either cartilage or fibro-cartilage. The tumour, removed by Hunter, already alluded to, consists of a series of large oval or spherical nucleated cells, imbedded in a firm intercellular substance, which is in some parts structureless, in others more or less fibrous; the cells, Fig. 123, contain nuclei which are very granular, and of a brown colour.

FIG. 123.



Section of an *Enchondroma* from
the neck.

FIG. 124.



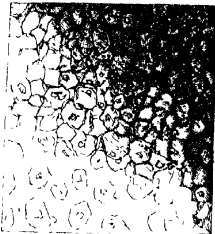
Section of an *Enchondroma* from
one of the ribs.

Fig. 124 represents the structure of an enchondromatous tumour, removed after death from the rib of a man; it more nearly resembles fibro-cartilage than true cartilage, many cells occurring among a dense mass of fibres. In an *Enchondroma* from the cheek, as shown by B, in Fig. 125, some of the cells have

nuclei of large size, others, as at A, are dark and granular, the latter being in the first stage of ossification. In the specimen from which this preparation was taken, there were many points or spicula of bone, but the fibres were least numerous in these parts.

FIG. 125.

A



Portion of an *Enchondroma* from the cheek: A, cells and matrix becoming ossified. B, cells with nuclei.

FIG. 126.



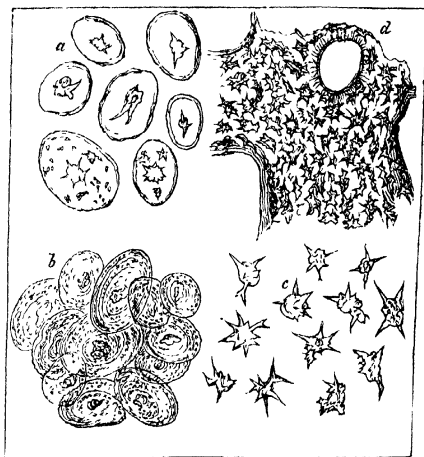
Portion of an *Enchondroma* from the hand: A, cells imbedded in a fibrous matrix. B, cells detached from the matrix.

The next specimens I shall describe are of great interest, as they throw considerable light on the formation of the lacunæ of bone. The first, Fig. 126, is a thin section of one of the tumours developed from the phalanges, &c., of a hand, removed some years since by the late Sir Astley Cooper; it is composed of a series of small cells, somewhat resembling the lacunæ of bone, each cell having branching tubes or canaliculi projecting from it in all directions. Some of these cells, as shown at A, are firmly imbedded

in a fibrous matrix; others, in the same tumour, as at B, can be separated from the matrix, proving that they are true cells, and not mere vacuities in the hyaline substance. In order to demonstrate that these cells are, in all probability, altered nuclei, the original cell-walls of which have disappeared, I shall describe the structure of a section of the enchondromatous tumour of the leg, before referred to in page 164, as having been lately removed by Mr. Lloyd at St. Bartholomew's Hospital; it was a large mass, measuring twenty-two inches in circumference, and very thin sections exhibit cells of an oval or circular figure, having a central nucleus and a concentric laminated deposit. Some of these, represented in Fig. 127, *b*, exhibit a minutely granular structure, as though ossification had commenced in them; other parts of the section exhibit cells of similar size, in which the nucleus is not only well developed, but occasionally small projecting points, like commencing canaliculi, may be observed, as in Fig. 127, *a*. As soon, however, as the canaliculi become somewhat more evident, the cell-wall disappears, and we then find cells of similar shape to those in the first specimen, but of larger size, Fig. 127, *c*. It sometimes happens that these cells are met with either above or below a cartilage cell, and it then appears as though the altered nucleus were still within a cell wall; but careful focussing will prove that this view of their relative situation is incorrect. In one part of the specimen, there is a thin

layer of bone, in which the lacunæ are large, and have but few canaliculi; these, as shown in Fig. 127, *d*, very much resemble the nuclei of the cells, and, in all probability, were formed from them.

FIG. 127.



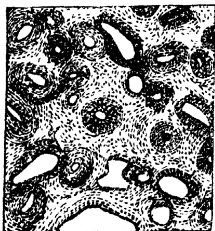
Cells and bone from an *Enchondroma* of the tibia: *a*, cells each having a stellate nucleus; *b*, cells showing laminated deposit and ossific granules; *c*, stellate nuclei; *d*, thin portion of bone in connection with the cartilage.

With regard to the formation of the lacunæ of bone, two views are now entertained by different histologists. The first is that given in the "Physiological Anatomy" of Professors Todd and Bowman, in which it is stated that the lacunæ are developed from the nuclei of the cartilage cells; the other that of Mr. Tomes, published in "Todd's Cyclopædia," article "Osseous Tissue," in which it is asserted that the lacunæ are not developed

from the nuclei of the cartilage cells, but are cavities left in the newly formed bone, from which canaliculi are subsequently developed. The last described specimen of enchondroma, however, tends to prove that the view entertained by Todd and Bowman is the more correct.

In order to understand what I am now about to describe, it will be necessary for me to give a brief account of the structure of bone. If we take, for example, one of the long bones of the body, we shall find that it consists of a shaft and two extremities; if the same bone be divided transversely, its centre will be found to be hollow, or occupied by a spongy kind of bone, which has received the name of cancellated structure. Within the hollow, the marrow is contained, and the cavity, as you are well aware, is called from this circumstance the medullary cavity. If we examine the outer surface, we shall find a series of minute holes or foramina through which blood-vessels pass towards the interior of the bone. If now,

FIG. 128.



Portion of a transverse section of a human femur magnified 40 diameters.

a slice sufficiently thin to be transparent, be made and examined with a power of forty diameters, a series of holes will be noticed, around which innumerable black spots are deposited in concentric circles, as shown in Fig. 128, these are the Haversian canals, and through them the

blood-vessels for the nutrition of the bone are transmitted. These canals are larger on the inner or medullary surface of the bone than they are on the

FIG. 129.



Portion of a transverse section of a femur magnified 200 diameters.

outer. Let the same section be next examined under a power of two hundred diameters, a concentric arrangement of laminae, as represented in Fig. 129, will be seen around each canal, and the black dots before alluded to will now present a spider-like appearance; they are known as the lacunae, or bone-cells, and each consists of a central part or body, from which a number of minute tubes termed canaliculi proceed. The canaliculi nearest to each Haversian canal open into it, whilst those more distant from the same canal, anastomose with the canaliculi of the next lamina; those of the outer row of bone-cells do not anastomose with the canaliculi of neighbouring laminae, but nearly all bend back and join those of the preceding lamina. By this arrangement, a white line may be observed to surround the outer part of each of the concentric circles; so that the bone may be said to be built up of a series of Haversian systems. If the same bone be divided in a vertical direction, as shown by Fig. 130, the course of the Haversian canals may be readily seen; they run in parallel lines, and are connected together by oblique,

FIG. 130.

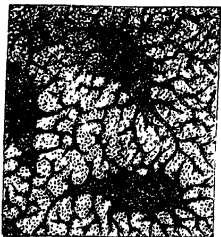


Vertical section of human femur
magnified 40 diameters.

or more or less transverse branches. Within them, the blood-vessels, from which the nutritious matter is poured out, are contained; this being taken up by the canaliculi opening into the canals, is by them conveyed to the whole concentric arrangement of bone-cells; each bone-cell, therefore, may be considered as a reservoir of nutriment for the bony matter surrounding it.

It may be asked, since all the structures I have described are of a tubular character, where is the osseous matter? To observe this, we must have recourse to much higher powers, and it will then be found that the bone consists of a congeries of more or less minute angular particles deposited in an organized

FIG. 131.



Portion of a transverse section
of a femur magnified 500 diameters,
showing the granules of
osseous matter.

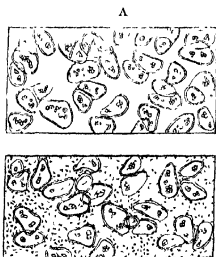
matrix. Fig. 131 is a representation of a portion of the same section of bone as Fig. 129 was copied from, but the power employed has been one of 500 diameters; the bone-cells and their canaliculi are well shown, and the minute dots occurring in all the spaces between the canaliculi are the granules, or

particles of osseous matter. If such a section be placed in dilute acid, these particles alone are removed, and the matrix in which they were imbedded presents a granular appearance. I have found, that in the crania of very small birds, as the *Canary*, where the bone is too thin to admit of bone-cells, the earthy particles are not only of large size, but each, as shown by B, in Fig. 134, is of a rhombohedral form. In the cartilage of the cranium of *Rana paradoxa*, minute needle-shaped crystals somewhat resembling the raphides in the *Squill* and *Hyacinth*, are occasionally found in the interior of each cell, thus proving that ossific matter may be deposited either in a granular or crystalline form.

In the cartilage of many fishes, as the *Shark*, *Skate*, and *Saw-fish*, the ossific matter is in the form of granules, and occurs principally in the neighbourhood of

the cells; in the *Skate*, the deposit sometimes takes place within the cell wall. To the latter I give the name cellular, and to the former inter-cellular ossification. In Fig. 132, are shown two portions of the cranial cartilage of a *Skate*; the one represented by A, exhibits a mass of cells imbedded in a more or less structureless matrix, whilst in

FIG. 132.



Cartilage from the cranium of a *Skate*: A, cells imbedded in a structureless matrix. B, granules of ossific matter around the cells.

the other, B, the granules of ossific matter around the

FIG. 133.

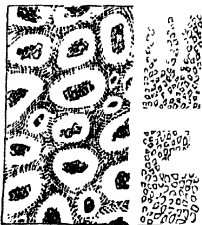


Vertical section of ossifying cartilage from the humerus of a foetal *Wolf*.

cells are well shown. A good example of intercellular ossification has already been given in Fig. 127, *b*. When a cartilaginous epiphysis is undergoing the process of ossification, the cartilage-cells first arrange themselves in linear series, and at the period of ossification, the cell-walls, as in Fig. 133, become more widely separated from the

nucleus, whilst the cells themselves are studded with minute ossific granules; if a section be made at right angles to the shaft, the walls of the cartilage-cells, as

FIG. 134.

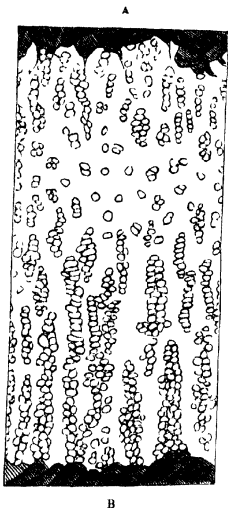


A, transverse section of ossifying cartilage from humerus of foetal *Wolf*. B, osseous granules from cranium of a *Canary*.

represented by A, in Fig. 134, will be found thickened by the granular deposit; subsequently, tubes of bone shoot up between the cells, and so enclose them. The part in which this process is going on may be readily distinguished by the arrangement of the cartilage-cells. In a vertical section of one of the short

phalanges from the foot of a young *Pig*, Fig. 135, a thin layer of cartilage will be seen between two pieces of bone; if this be more closely examined, it

FIG. 135.



Vertical section of one of the phalanges from the fore-foot of a *Pig*: A, distal extremity ossification going on slowly. B, proximal extremity, ossification proceeding rapidly.

will be found, that at the proximal extremity B, in which the formation of bone is going on, the cartilage-cells are arranged in linear series, but that at the distal one, A, only a trace of such arrangement is visible.

The ultimate osseous granules were first pointed out by Mr. Tomes, they cannot be well seen in very compact bone until it has been boiled, but may be readily distinguished in imperfectly developed bones. In a vertical section of a portion of the os frontis, belonging to the Histological Collection, a

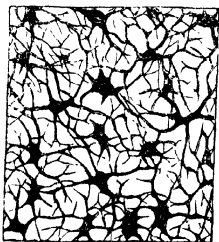
spot of imperfectly formed bone occurs near the centre, in which the granules are very visible. In certain forms of ossific deposit, as in the early stage of ossification of the coats of arteries, nothing but granules can be seen, and the same holds good in ossified fibrous tumours and cysts found occasionally in various parts of the body.

The ossific granules are generally discoverable in the pus which escapes from a necrosed bone. If a specimen

of this pus be examined with a power of five hundred diameters, a quantity of minute granular matter, readily soluble in dilute muriatic acid, may be distinguished among the pus corpuscles. This fact I noticed many years ago, but Mr. Bransby Cooper has ascertained by chemical examination, that a large amount of phosphate of lime is present in such pus, and announced his discovery in 1843, when Professor of Surgery to this College; so that it would appear that the pus has a solvent power, eroding or decomposing the animal matter, while the mineral constituent escapes with the pus in its granular condition.

The bone-cells or lacunæ vary in size and shape in the four great classes of animals, and I have ascertained that they bear a direct relative proportion to that of the blood corpuscles.* They are largest in reptiles, especially those of the *Perennibranchiate* order. In fishes their

FIG. 136.



Portion of the scale of a fish,
Lepidosteus osseus.

shape is very peculiar; and, what is remarkable, they are in some cases similar in form to the stellate cells found in the specimen of enchondroma from the hand, before described and represented in Fig. 126, as is illustrated by a thin section

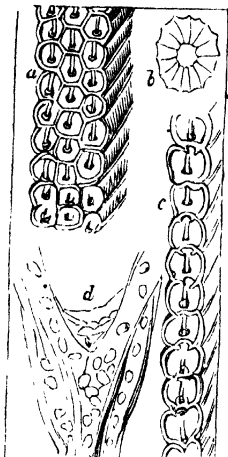
* "Transactions of the Microscopical Society," Vol. 11.

of a scale of the *Bony Pike*, of North America, *Lepidosteus osseus*, Fig. 136.

In *Mollities ossium*, there is a deficiency of the earthy constituent of the bone. The change first begins in the lucunæ, which become larger and larger, and the bone around them more and more transparent; finally, several lacunæ unite to form one cavity, which, however, does not long remain empty, but is occupied by a soft kind of adipose tissue, so that such bones are always extremely thin and full of fat. For this reason *Mollities ossium* may be considered as an example of the fatty degeneration of bone.

The last form of cartilage which I shall mention is of a very peculiar character, being always more or less tubular. It is found in the vertebræ of the *Vaagmaer* or *Riband-fish*,—a specimen of which, about three years since, was captured off St. Andrews. For our knowledge of this interesting structure we are indebted to the late Dr. John Reid; and the account of the anatomy of the fish was the last contribution to science made by that distinguished anatomist. A transverse section of one of the vertebræ, is illustrated at *b*, in Fig. 137. It exhibits four different structures: the first is an outer coating of dense areolar tissue; the second occupies the centre, and consists of a gelatinous substance somewhat resembling simple cartilage; the third composes the radii, which extend from the centre to the circumference; whilst the fourth consists of a firm fibrous structure, occupying all the

FIG. 137.



Sections from a vertebra of the *Vaagmaer*: *a*, three rows of cells from one of the radii; *b*, transverse section of a vertebra; *c*, one row of cells showing the tube passing through them; *d*, vertical section of one of the radii.

spaces between the radii, and forming the great mass of the body of the vertebra. It is to the radii that I would particularly direct attention, as these are composed of a material very like cartilage. In a thin section of the same vertebra, in which five rays may be distinctly seen, each is found to be composed of a series of thick-walled cartilaginous cells, arranged in linear series; some of the rays, as at *c*, being composed of one row; others, as at *a*, of three rows of cells. On carefully examining any one of these rows, an aperture of com-

munication between the cells may be observed, and through each of these apertures a delicate tube passes from the centre to the circumference. Whether this tube be a blood-vessel or an absorbent cannot be easily ascertained; its tubular character, however, is very evident. In a longitudinal section of a vertebra of the same fish, the radii, represented by *d*, are divided in the direction of their long diameter: they generally occur in bundles of three or four, and the apertures through which the tubes pass may be observed at

nearly equal distances from each other, and occasionally, portions of the tubes may be seen in the apertures. Dr. Reid described very accurately the structure of the vertebræ, and the arrangement of these thick-walled cells, but he appears to have overlooked the tubes passing through them, as no mention is made of their presence in his paper on this subject, published in the "Annals of Natural History" for 1849. They may not be present in every vertebra, but they are so in all the specimens in my possession, which were transmitted to me from Dr. Reid himself, through the hands of Dr. Macdonald.

FIBRO - CARTILAGE.

Before concluding the subject of cartilage, there is another tissue which, from being composed of two simple elements, fibrous tissue and cartilage, has been placed by Messrs. Todd and Bowman, as the last of the tissues in their table, namely, fibro-cartilage; but, as this is so intimately connected with some of the forms of articular cartilage and enchondroma, I think it best to consider it in this place.

Fibro-cartilage exists principally in articulations, occurring in the form of discs between the vertebræ in the human subject; these are highly elastic, and serve to diminish the shocks to which this portion of

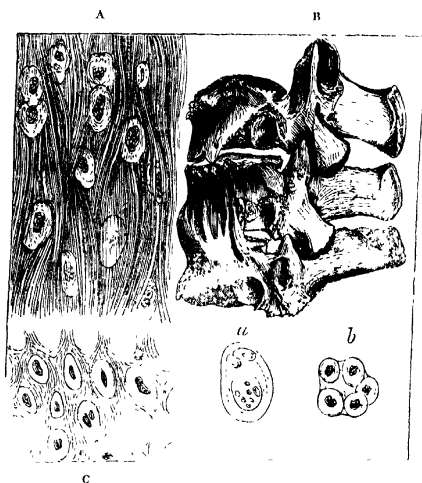
the body is subjected. In the *Cetacea* the discs are of immense size; and the articular surfaces of the vertebræ in many of these animals not being anchylosed to the bodies, may also be found detached as discs. These last are smooth and a little concave on their articular surface, convex and rough on their epiphysal; I remember when I first became connected with this College, that the late Mr. Clift told me he once met with a specimen about three or four inches in diameter, in the shop of a dealer in curiosities in the Strand, who gravely informed him more than once that he valued it above everything in his shop, as he considered it a most rare and beautiful example of a fossil crumpet, which it much resembles in appearance.

These discs are very abundant on the sea-shore in northern climates; and when Her Majesty's ship *Hecla* was wrecked, I was informed by one of the officers, that they served the crew of that unfortunate vessel as plates. The discs of fibro-cartilage between these vertebræ are often more than two inches thick. Masses of fibro-cartilage exist in certain joints, under the name of inter-articular fibro-cartilages. We have examples in the temporo-maxillary and sterno-clavicular articulations of the human subject. When either of these is divided transversely, and a section made sufficiently thin for examination by the microscope, it will be found that it is composed chiefly of a net-work of fibres, within which a few cartilage cells are enclosed.

The cells, Fig. 138, A, are large and tolerably

numerous, in sections of the outer portion of an intervertebral disc; in the centre, which is more pulpy than the outer part, the fibres are fewer in number, and the cells, as shown at *a*, *b*, larger and more abundant. Many of the examples of articular cartilage, especially those from fishes and birds, as well as specimens of

FIG. 138.



A, fibro-cartilage from outer part of an intervertebral disc; *a*, *b*, cells from the centre of the same disc. *B*, three dorsal vertebræ showing ossification of the anterior common ligament, with absence of the intervertebral disc. *C*, fibro-cartilage of epiglottis.

enchondroma, are composed of fibro-cartilage, characterised by the presence of white fibres and cartilage-cells.

Modified forms of fibro-cartilage exist in the epi-

glottis of the human subject, as shown at c, and in the auricles of the ear of the larger mammalia. In these situations, the cells are readily separated from the matrix ; indeed, they often drop out, and leave the fibrous framework entire.

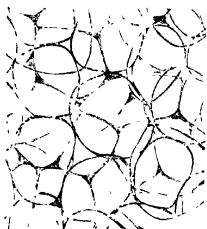
Fibro-cartilage is not so prone to ossification as the simple fibrous structures ; for in two examples of ankylosis of the vertebræ, selected from a large number in the Museum, the discs have, in each case, disappeared, and the ossific matter is confined to the fibrous tissue, or anterior common ligament, which binds them firmly together ; in some instances, the space originally filled by the disc is still present, but remains unoccupied by bone. A striking specimen, illustrative of this fact, is represented in Fig. 138, B. In the two upper vertebræ, the ligament has become ossified, and a considerable quantity of bone has been formed, so as to cover the anterior part of the inter-vertebral space ; there is, however, no junction between the two vertebræ, but between the second and third the union is complete, and in both cases, the space originally occupied by the inter-vertebral disc is empty. This fact is quite as evident in the spine of the lower orders of mammalia as in man, and is very common in the *Horse* and *Sheep*.

LECTURE XVI.

ADIPOSE TISSUE.

NEXT in our order of arrangement, among the true cellular tissues, is *Adipose tissue*, which consists of cells having walls composed of structureless membrane, containing within them the substance known as *fat*. This exists, in ordinary animals, in three states, either as oil, lard, or tallow; but in one species of *Whale*, the *Physeter macrocephalus*, it is in the form of spermaceti. The three first being distinguished by their relative firmness at ordinary temperatures, while the last differs *in toto* in its chemical properties. In the majority of works on anatomy, and in common parlance, the term *fat* is given to masses of these cells, but in modern science *adipose tissue* is the name applied to the mass of cells, and *fat* to their contents. The cells of adipose tissue, when occurring singly are globular, but when subjected to

FIG. 139.



Cells of adipose tissue.

pressure as in Fig. 139, they are, like vegetable cellular tissue, of a more or less dodecahedral shape. In the young subject, they vary in diameter from $\frac{1}{300}$ th to $\frac{1}{800}$ th, and in the adult, they are rarely smaller than $\frac{1}{700}$ th of an inch. When first developed in the embryo, they have a nucleus, but this very soon disappears. Adipose tissue exists in the form of lobules, which may occur singly or in masses of many pounds' weight. A certain amount of it is considered a sign of health, but an excess, especially if it be in one mass, as in certain tumours, constitutes disease.

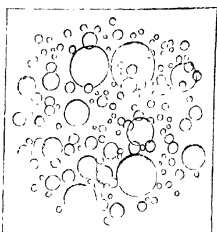
In all works on anatomy and physiology, even of so late a period as last year, it is distinctly stated, that adipose tissue exists in invertebrate animals; this, however, I find to be incorrect, and it cost me no small amount of labour to prove it. Fat certainly does exist in insects, crustacea, and mollusca, but no true adipose cell is ever present; it could not be nourished without its accompanying blood-vessels, and these are not found in invertebrata. The tissue resembling adipose tissue usually belongs to the liver or other glandular organ, and the fat exists in its cells in the form of oil.

In the liver of the larva of a *Goat Moth*, *Cossus ligniperda*, which consists of a series of cells or vesicles, containing a large number of globules of oil, and again,

in another specimen, taken from a *Cockroach*, there are tubes, also full of oil globules, but in neither case, and not even in the *Cephalopoda*, is the oil contained in adipose cells.

As soon, however, as we pass the barrier between the invertebrate and vertebrate sub-kingdoms, we find that even in the lowest members of the class of fishes, true adipose cells occur, and all are doubtless aware, that in the liver of the *Cod*, and of many cartilaginous fishes, fat exists in the form of oil without any adipose tissue;—in this particular, the liver resembles that of an invertebrate animal. If a portion of the liver of a *Cod* be examined, it will be seen, that with the exception of a

FIG. 140.



Oil globules from the liver of the
Cod.

few secreting cells, it is composed of a mass of oil globules of various sizes, as shown in Fig. 140; but in a specimen from the peritoneum of the same *Cod*, a mass of adipose cells full of a dark brown liquid oil are visible. The adipose cells are grouped in lobules, and surrounded by

areolar tissue, which invests the lobules and supports the capillaries distributed to the cells. This is well exhibited in two preparations, one of the subcutaneous adipose tissue of a young child, the other of the same tissue from an adult, in which the adipose cells far exceed those of the child in diameter.

Hunter's observations on this subject, contained in the third volume of the *Physiological Catalogue of the Museum*, are so valuable as to merit an attentive perusal; they contain, however, a few trifling errors which arose from his not being aware of the existence of the adipose cell, especially in the *Whale*, the fat of which animal he supposed to be contained in the interstices of the fibres that constitute a great portion of the blubber. A preparation put up to demonstrate this fact is still in the Museum, but the receptacles it exhibits are for the lodgment of the adipose cells containing the oil, and not for the oil itself. Another preparation, is a section of the skin of a *Whale*, taken from near the tail, also put up by Hunter, to show that in this part of the animal there are no receptacles for the oil. The chief value of the adipose tissue of the *Whale* tribe consists in its containing oil which is liquid at ordinary temperatures; the train oil of commerce; the fat of the *Bear* is also very valuable on the same account, and is largely employed by the perfumer. I once had an opportunity of dissecting a *Bear*, and, although it was during frosty weather, the quantity of oil that flowed from between the muscles was very great, amounting to many gallons, and hence I concluded, that the value of the oil of the *Bear*, or grease—as it is usually termed—to the perfumer, depends on its continuing in a fluid state, even at so low a temperature. The nearest approach to the fat of the *Bear*, is perhaps, the marrow from the extremities of the long bones of ruminants, which is often

used as a substitute for bear's grease. From the whole of this tribe we procure a very firm fat known as tallow; in the *Pig* it is still firmer, and called lard; if a portion of either of these substances be cut transversely, the fat is so dense as to allow of the adipose cell being divided, and such tallow or lard is perfectly solid in all temperatures of this climate, and is capable of being employed in the manufacture of candles. In the *Turtle*, there is under the carapace a quantity of adipose tissue contained within delicate areolæ, formed principally of loose white fibrous tissue, and is well known as the green fat, being much prized by epicures. This fat is more digestible than that from ordinary animals, and I have frequently heard it remarked, that those persons who cannot easily digest the fat of beef or mutton, can consume large quantities of the fat in question without annoyance.

I have stated, that the adipose tissue is supported by a fibrous net-work; this holds good in the majority of cases, but, in the marrow of bones, no supporting tissue is present, and I here take the opportunity of demonstrating a point of some interest, which is of constant occurrence throughout the vertebrate kingdom, viz., that in the bones of the arm or leg, the marrow of the humerus and femur is exceedingly firm, whilst that of the lower part of the tibia or metatarsal bone is always more or less liquid, and it is from these bones that the ordinary neat's foot oil is procured. The same thing is evident even in skeletons, in those of birds, it may be

observed that the bones of the extremities are greasy at their distal ends, because the contents of the adipose cells are always of a liquid nature, and have little or no tissue to support them.

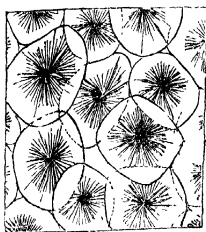
According to chemists, fat consists of a liquid and solid principle, the former being termed *elaine*, the latter *margarine*; in all the firmer fats, such as lard, a third principle, termed *stearine*, is also present. When speaking of oil in vegetables, I noticed the analogy between the fatty substances derived from plants and animals, and I mentioned that a *stearine* had for some time been procured from palm-oil, either by distillation, or by subjecting it to great pressure. *Stearine* may be obtained from human fat, and cannot readily be distinguished from that of vegetable origin.

It is generally known that the *elaine* and *stearine* of the fats, are compounds of the *oleic* and *stearic* acids, with a base termed *glycerine*, a substance now frequently employed in medicine, and also in mounting microscopical objects. This material is extensively obtained in the manufacture of soap. When oils or fats are boiled with caustic alkali, the compounds of *stearic*, *oleic* and *margaric* acids with *glycerine*, are decomposed, the former combining with the alkali, while the latter is set free, and is found in the soap- lees; from which it is separated by a chemical process. The purest *glycerine*, which is almost colourless, is obtained in the manufacture of lead plaster. In this process, oil, litharge (oxide of lead) and water are boiled together, the oxide

of lead combines with the fatty acids, and the glycerine is separated in a nearly pure state.

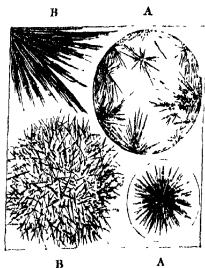
It sometimes happens, especially in the adipose tissue of old persons, that the solid element, or margarine, separates in the form of acicular crystals from the elaine. In a specimen of adipose tissue from a female, seventy years of age, every cell (Fig. 141) contains a stellate mass of these needle-shaped crystals. This fact is more strikingly exemplified in the adipose tissue of the *Sper-*

FIG. 141.



Adipose cells, each containing needle-shaped crystals of margarine.

FIG. 142.



Adipose tissue of *Sperm-whale*.
A A, cells containing crystals of spermaceti. B B, crystals of spermaceti on the outside of cells.

maceti Whale, the adipose cells, as shown by Fig. 142, are of large size, and in every cell may be seen the crystalline substance known as spermaceti. This substance, however, as represented by A B, frequently occurs in masses of needle-shaped crystals external to the cells, but in some instances tabular crystals are more common in these situations than the acicular.

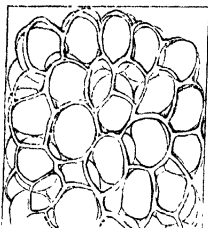
The subcutaneous adipose tissue is most abundant in animals destitute of hair, such as the *Whale*, and even man himself; in other animals, especially ruminants, it is stored up around the loins and kidneys, and that obtained from the latter situation has received the name of suet. The *Whales*, on the contrary, have no adipose tissue within the cavity of the abdomen, and some wild animals, especially the *Hare*, have seldom a trace of adipose tissue in any part of the body. In fishes, adipose tissue occurs among the muscles; but in the *Cod* and some of the cartilaginous species it is found in the liver in the form of oil. In reptiles, as the *Frogs* and *Newts*, it is stored up against winter in the form of long cœcal appendages situated above the testicles. If a *Frog* be examined in the autumn, these appendages will be found of large size; but by the spring they will have nearly disappeared. The same thing occurs amongst hybernating quadrupeds, the *Dormouse* and *Hedgehog* for example, but in these animals the fat is principally subcutaneous, forming in fact a winter overcoat. In serpents the fat exists in the form of lobules attached to the sides of the mesentery; in turtles it is principally beneath the carapace; in birds it is chiefly subcutaneous, and in the peritoneum; in many of these animals, especially those of the order palmipedes, the adipose tissue contains an abundance of oil.

Having made frequent allusion to a peculiar kind of fat found in the *Sperm Whale*, and known by the name of spermaceti, I will now describe it more parti-

cularly. It is a crystalline substance, of a white or yellowish white colour, which is deposited in the large cranial cells or interspaces of the *Spermaceti Whale*. During the life of the animal it is liquid, but it readily crystallizes and separates after death. It was formerly considered useless, and hundreds of tons have been thrown into the Thames, but it is now largely employed in the manufacture of candles, and is even more valuable than the oil itself, from which it separates in flaky crystals. When spermaceti is exposed to a heat of 115° Fahrenheit, it melts, and again crystallizes on cooling; in this condition it has the property of polarizing light, and exhibits a beautiful series of colours. The same power of polarizing light is also possessed by a substance somewhat like spermaceti, produced by the decomposition of certain animal tissues, especially the muscular, and known by the name of adipocire. A fine specimen of this material, formed from the thigh of a man by the action of water, is preserved in the College Museum. Like spermaceti, adipocire is easily melted, and crystallizes on cooling.

I have already stated that the cells are arranged in lobules, and that each lobule is invested by areolar tissue, which passes among the cells, and gives support to the blood-vessels. The blood-vessels rapidly divide into a capillary network, which not only surrounds the individual lobules, but branches in the form of loops encircle each fat-cell. These capillary loops are represented, in Fig. 143, under a magnifying power of two hundred and fifty

FIG. 143.



Portion of an injected lobule of human adipose tissue.

of the cells are readily distinguished when viewed by transmitted light. In birds, the adipose cells are of smaller size than in mammalia, and when injected the capillary net-work is closer. Small lobules of adipose

FIG. 144.



a b, injected lobules of adipose tissue from the skin of a *Pigeon*; *c*, portion of the same magnified 200 diameters.

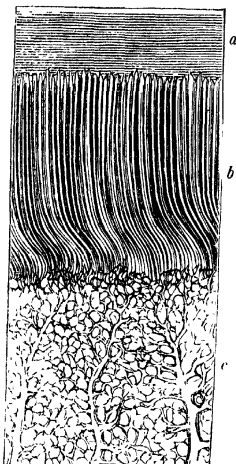
tissue sometimes surround the pulps upon which the feathers are formed, and the capillaries of these lobules very much resemble those of some glandular organs, as is strikingly exemplified in a portion of the skin of a young *Pigeon*, Fig. 144. At *a* and *b*, are shown the capillaries of two lobules, magnified forty diameters, and at *c*, a portion of one of the same, magnified two hundred diameters.

When speaking of the adipose tissue of the *Whale*, I mentioned the receptacles between the fibres for the lodgment of the cells; a specimen of this tissue would,

diameters. This vascular network can only be demonstrated by injected specimens, and the arrangement of the vessels may be rendered more distinct by dissolving out the fat by oil of turpentine. When large masses of adipose tissue are treated in this way, the walls

when injected, exhibit an extraordinary amount of vascularity. An injected specimen of the blubber of a young *Porpoise*, is represented by Fig. 145. The upper part

FIG. 145.



Vertical section of the skin of a young *Porpoise*: *a*, cuticle; *b*, papillae; *c*, vessels of the adipose tissue, or blubber.

of the preparation, *a*, exhibits the non-vascular cuticle, into which long papillae, *b*, project; below these are seen numerous trunks, *c*, giving off capillary vessels which belong to the adipose tissue. The amount of vascularity, therefore, of the blubber of a large *Whale* must be truly astonishing, if we may judge from this specimen from one of the smallest of the cetacea. A somewhat similar structure to that of the blubber of the *Whale* occurs in the *Pig*, which, when salted and dried,

is known as bacon. In this substance the capillaries, when successfully injected, are as numerous as in other specimens of adipose tissue.

The adipose tissue of young animals as in children, generally consists of a series of small oval, or circular lobules scattered throughout the areolar tissue; if the injection be perfect, it will be found that the capillaries of the cells are much smaller than those of the adult

human subject, represented in Fig. 143. In fatty tumours, the fat is usually more or less yellow, and contains few if any vessels which bleed on its removal or when cut ; but it sometimes happens that the mass is of a red colour, and contains a very large amount of blood. A tumour of this character, removed after death from the mesentery of a child, by Mr. Pittard, formerly one of our students, had at first sight an appearance like that of malignant disease, and when an incision was made into it, a large quantity of blood escaped. Its true nature was only ascertained by microscopic examination, when it turned out to be nothing more than a mass of adipose tissue, and although it has been preserved in spirit and exposed to the light for the last two years, it still retains a portion of its red colour.

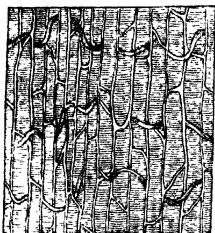
LECTURE XVII.

FATTY DEGENERATIONS.

THERE is a particular morbid condition of many distinct organs, in which fatty matter, or true adipose tissue, takes the place of healthy structures. The first of these abnormal changes is called fatty degeneration, but to that of the second the term fatty substitution might be applied; they occur most frequently in muscular tissue. Before, however, I can present a satisfactory idea of the commencement of this disease, it will be necessary for me to describe very briefly the normal anatomy of muscular tissue. For our knowledge of the minute anatomy of muscle we are principally indebted to the labours of Mr. Bowman, and the account I shall give will differ but little from that published by him in the first part of the "Philosophical Transactions" for 1841. Every voluntary

muscle consists of a series of fibres, each of which is termed a *fasciculus*, and each fasciculus is invested by a sheath of structureless membrane, termed the *sarcolemma* (Fig. 147, B). The muscle itself is surrounded

FIG. 146.



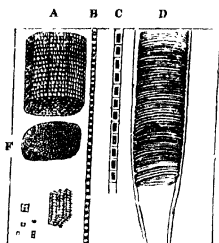
Capillaries of voluntary muscle.

by areolar tissue, which dips in among the fasciculi, and gives support to the blood-vessels and nerves. If a muscle be injected, the capillaries, as represented in Fig. 146, are readily seen; they run in parallel lines between the fasciculi, and transverse connecting branches are given off

at tolerably regular distances.

The fasciculi exhibit transverse and longitudinal striæ, but, in most cases, the former, as shown in Fig. 147, A, are more plainly exhibited than the latter. In some animals the fasciculi break up transversely, in others longitudinally, so that, in the one case, we have a series of discs, and in the other numerous filaments termed fibrillæ. The fasciculi of the *Eel* readily break up into discs, whilst those of man and most mammalia commonly separate into fibrillæ. If the flat surfaces of the discs, at F, in Fig. 147, be examined, they present a granular aspect, which is due to their being made up of the ends of the fibrillæ; and, if the fibrillæ be viewed with a power of five hundred diameters each one, as shown at B, will exhibit a beaded structure, the

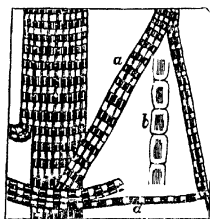
FIG. 147.



A, portion of a fasciculus of voluntary muscle of an *Eel* splitting up into discs. B C, fibrillae. D, fasciculus invested with its sarcolemma. E, masses of myoline detached from the fasciculus.

Mr. Lealand; on the lower edge of one of the fasciculi are distinctly seen the very delicate fibrillae *aa*, and, if the power with which this specimen is examined be sufficiently high, the central mass of myoline *b* may

FIG. 148.



Fasciculus of voluntary muscle of a *Pig*: *aa*, fibrillae; *b*, enlarged representation of one of the fibrillae.

If the fasciculi have been kept long in spirit or acid, the fibrillae break up, and the masses of myoline are found either in short lengths or in detached

part forming the bead being a minute portion of muscular substance, termed *myoline*; but if the power be increased, the masses of myoline (*c*) will be found to be surrounded by a thin cell-wall. In the muscular substance of the *Eel*, the structureless sarcolemma surrounding a fasciculus (Fig. 147, B) is readily seen. In Fig. 148 is represented a portion of the muscle of a *Pig*, prepared by

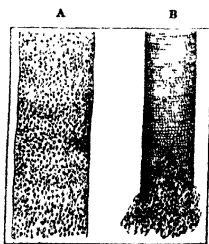
The fibrillae vary in size in different portions of the same muscle, in the *Skate* and *Shrimp* I have seen specimens more minute than $\frac{1}{60000}$ th of an inch; in these cases the particles of myoline can be discerned, but not the cell-wall around them.

pieces, in all parts of the field of view. A specimen of this kind from the *Eel* is represented in Fig. 147, E; the same thing is very common in other fishes, especially the *Lamprey* and *Lancelet*.

Before fatty degeneration commences in voluntary muscle, the transverse striæ disappear; and I have long known that the first trace of this disease is marked by a disturbance of the particles of myoline, which appear as so many very minute granules scattered irregularly within the sarcolemma, leading one to suppose that the delicate cell around each particle had given way, thereby allowing the myoline to escape, and destroying all regularity both of the transverse and longitudinal markings. As the disease progresses, the myoline is replaced by minute, highly-refracting globules of oil, until at last the whole sheath is full of them.

In a specimen of this diseased condition of mus-

FIG. 149.



A, fasciculus of voluntary muscle full of oil globules.
B, fasciculus of voluntary muscle exhibiting a disturbance of the particles of myoline.

cle from the human subject, Fig. 149, B, the transverse striæ are visible in the upper part, and a partial disturbance of the myoline in the lower; in another preparation (Fig. 149, A) the disease has so far advanced that all trace of striæ is completely lost, and globules of oil, in this case of nearly equal size, but in others of variable diameter, occupy the sarcolemma. The

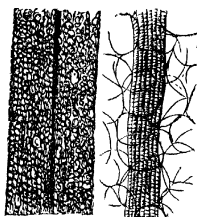
fibres of the heart are very subject to fatty degeneration, and for our knowledge of this disease we are, in a great measure, indebted to the labours of Dr. Ormerod; but the subject has been lately investigated with great care by Dr. Richard Quain; and in his paper, published in the fifteenth volume of the "Medico-Chirurgical Transactions," you will find all that is at present known respecting it. A very excellent example of fatty degeneration of the muscular fibres of the heart, is one taken from a man a hundred and three years of age, for which I am indebted to the kindness of Dr. Edward Smith, it exhibits the transverse striæ in some parts, but in others, as in Fig. 142, A, these are replaced by highly-refracting globules of oil. I have lately had the opportunity of examining a most interesting case in which the disease was present in the voluntary muscles of the extremities. In one family of nine children, six of whom were girls and three boys, all the girls were perfectly healthy, but the boys, on arriving at the age of three or four, began to lose the use of their limbs. One of them, the eldest, has lately died, and, on examination of the brain and spinal chord, both were found to be healthy, the muscle, however, had not only undergone fatty degeneration, but the fasciculi themselves were much diminished in size, which would, of course, account for the want of power in the limbs. This disease from the first was supposed to be seated in some part of the nervous system, probably arising from imperfect innervation of the muscle;

but the discovery of its real seat will, it is to be hoped, lead to such a mode of treatment as may be beneficial to the two afflicted survivors.

Fatty degeneration of voluntary muscle is very common among the lower animals. All are aware, no doubt, of the difference in colour between the flesh of the breast of a *Fowl* and that of its legs, the former being more or less white, the latter of a reddish hue. If that from the breast be examined, traces of fatty degeneration are very apparent in the fasciculi, arising, no doubt, from the want of use of the muscle in the act of flying. The muscular structure of the legs, on the contrary, which are always in exercise, is perfectly healthy. I have detected the same disease in the muscles of the legs of the *Ostriches* kept for a long time in the Zoological Gardens. These from want of use, are perceptibly whiter than those employed merely in the support of the body, and also exhibit a considerable amount of fatty degeneration. The same disease I have also found in their bones; and it is a fact well known to the keepers, that when they once take to lying down, their doom may be said to be sealed. A knowledge of this circumstance may perhaps lead to the more successful preservation of these gigantic members of the feathered tribe. In the *Sheep* many instances are on record in which almost the entire muscular substance of the trunk has been converted into adipose tissue. In the Pathological Series is a mutton chop, Prep. 10, nearly all the muscular substance of which

is replaced by adipose tissue ; in this case the disease no doubt first commenced in early life, and as the fasciculi diminished in size, the adipose tissue was deposited to occupy their place, forming a good instance of fatty substitution. A portion of a fasciculus, surrounded by adipose cells, is represented in Fig. 150, B, and an entire fasciculus, full of nearly equal-sized globules of oil, in Fig. 150, A.

FIG. 150.



A, fatty degeneration of voluntary muscle. B, substitution of adipose tissue for voluntary muscle.

The leg of a man thirty-five years of age was removed a few months since at King's College Hospital, by Mr. Partridge, in which all the muscles had been replaced by adipose tissue. The limb had been rendered useless by an attack of paralysis, occurring three years after birth. Only a few fasciculi could be

discovered amongst the adipose cells, and these were of very small size and perfectly healthy. Fatty degeneration appears also to occur in osseous tissues, and indeed the disease termed *mollities ossium* is of this nature. All bones so affected have thin walls, are always more or less soft, and contain an abundance of oil. I have examined the bones in several cases, and found that the disease first commences in the bone cells, the cell itself becoming larger and larger, its canaliculi disappearing, and several of these cells uniting to form a cavity, in which oil globules soon make their appearance,

all the parts of the bone in the neighbourhood of the cells, becoming at the same time thin and transparent from the removal of the granules of earthy matter. In a vertical section of the lower end of the tibia, from a case of *mollities ossium*; the walls of the bone are exceedingly thin, and so soft as to be readily cut with a knife, the entire medullary cavity, and all that remains of the cancellated structure, being full of oil and adipose tissue.

There are still one or two more examples of fatty degeneration of tissues, of sufficient importance to merit notice. The first of these is a deposit of fatty matter between the layers of the cornea, giving rise to the *arcus senilis*. The discovery of the true nature of this change, which is common in the eyes of old people, is due to Mr. Canton, who has published an account of it in the "Lancet" for 1850.

In a vertical section of a cornea, given to me by Mr. Canton, the *arcus senilis* has formed, and between some of the layers of which the cornea is composed there is a deposit of small, highly-refracting globules of oil. The arcus is not situated in that part of the cornea joining the sclerotic, but a little nearer the centre, there being generally a transparent zone between the sclerotic and the arc. The last example of degeneration of tissues of which I shall speak, is the formation of *Adipocire*, which takes place after death, when flesh is exposed to a certain amount of moisture, or to a running stream of water. A preparation of the thigh of

a human subject converted into adipocire, was presented to the College some years ago by the late Regius Professor of Medicine at Oxford, Dr. Kidd. It was a portion of a subject which had been partially dissected, and, not being further required, was placed in a pit near the dissecting-room, into which fresh water was occasionally admitted. When a mass of adipocire is handled, it will be found to have a soapy feel, and to possess little or no odour. On exposure to heat, it readily melts like spermaceti, crystallizes again on cooling, and also polarizes light. When examined microscopically in the fluid state, or after solution in ether, no trace of muscular substance remains, the residue consisting principally of areolar tissue. A thin slice exhibits no appearance of cellular structure. Adipocire, like spermaceti, is capable of being made into candles; and on the discovery of this substance, many years ago, a patent was taken out for the conversion of the offal of slaughter-houses into adipocire, but the process died with the patentee. A very large quantity of adipocire was found at the commencement of the present century in the burial-ground of Les Innocens at Paris, where one thousand five hundred bodies had been buried in one pit, most of which had been converted into this material by the action of water. A considerable quantity of adipocire was once formed in a pit in this College, into which all the parts removed in dissection are thrown; the adipocire, however, in this case, was derived principally from the muscular substance of a young *Elephant*.

LECTURE XVIII.

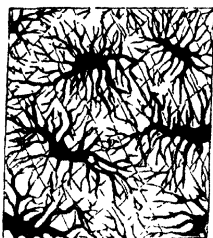
PIGMENT.

I NOW arrive at the description of the last variety of permanent cellular tissue occurring in the human subject, *pigment*. This consists either of a solid or fluid matter, contained within a cell-wall. When speaking of pigment in vegetables, I stated that, in some few cases as in *Ferns*, we had colour belonging to the cell-wall itself, but in all other instances, the various and beautiful hues of flowers were produced by a fluid colouring-matter occurring within the cells. We have likewise a striking example of fluid colouring-matter in animal cells, in the blood discs, but in animal tissues generally the pigmental matter occurs in the form of granules. The most striking examples of pigment occur in the eye, upon the choroid coat of which is a distinct layer of hexagonal cells, most probably epithelial, termed the

pigmentum nigrum, within these are found innumerable minute granules, which, if examined soon after death, exhibit a molecular movement. The size of these granules does not generally exceed the $\frac{1}{20000}$ th of an inch in diameter, the depth of the colour depending upon the quantity aggregated within a certain space. The granules are said to consist of a peculiar animal principle, the chief constituent of which is carbon, and on this account neither the strongest acids nor chlorine is capable of destroying the colour. The most common form of the cells is hexagonal, as in the *pigmentum nigrum* before described; but between the choroid and sclerotic they are somewhat fusiform, and occasionally have bifid extremities. In some of the lower animals, as the reptiles and fishes, they have a stellate appearance, and in some cases bear a strong resemblance to bone cells. The principal seat of pigment in animals is the cuticular layer of the skin, in which it also occurs in hexagonal cells. In the negro the black colour was formerly supposed to occur only in a distinct layer of the skin, termed the *rete mucosum*, but such is now found not to be the case, the *rete mucosum* being merely the layer of cuticular cells last formed, and which contain pigmental granules. Similar cells are present in Europeans, those of the last deposited layer being always darker than those nearer the free surface; the difference in quantity of the pigment in the cells gives rise to all the varieties of colour which the skin of the human race presents. In Albinoes the cells

are present, but the granules, if not absent, are so few in number as to occasion little or no shade of colour. The skin of a *Lamprey*, Fig. 151, exhibits a number of

FIG. 151.



Pigment cells of the skin of
a *Lamprey*.

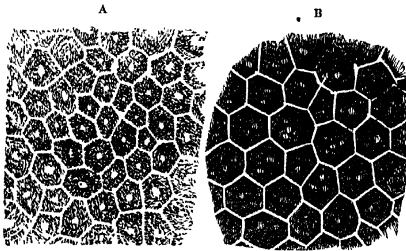
large cells of stellate figure, somewhat like the lacunæ of bone. The red spots on the skin of the *Plaice* are produced by the presence of minute irregular cells occurring in great abundance between others of large size, which are of a black colour, and stellate figure. Pigment-cells are very frequently found in the

peritoneum of fishes and reptiles.

In the skin of a *Newt* (*Triton palmatus*), the pigment is very abundant, giving a marbled appearance to the animal; the cells are of a stellate figure, and are chiefly arranged in circles, the central part of the circle being a follicle, which, in some cases, contains granular matter. Numerous pigment-cells are present in the skin of the web of the frog's foot; these always excite attention when the circulation in the capillaries is seen for the first time. In some of the Reptiles there are pigment-cells containing a white material; in the iris of a Tiger-boia (*Python tigris*), a collection of white pigment-cells exists, in which the branches of the cells are of great length, and when these are viewed by transmitted light they appear perfectly black. I am still uncertain whether the branches of these cells ever

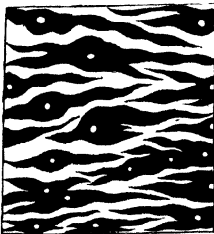
communicate or anastomose; in the majority of cases they certainly do not, but in the last named instance this point cannot be easily determined. The *pigmentum nigrum* from the eye of a *Sheep*, Fig. 152, A,

FIG. 152.



A, pigmentum nigrum of the eye of a *Sheep*. B, pigmentum nigrum of the eye of an adult human subject.

FIG. 153.



Pigment-cells between the choroid and sclerotic coats of the eye of a *Sheep*.

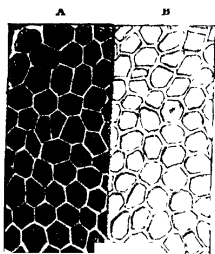
consists of cells of hexagonal figure, full of black granules; if, however, the posterior part of the choroid be examined, as in the specimen, Fig. 153, it will be found that some of the cells are fusiform, whilst others are bifurcated at one or both extremities; in the centre of each cell is a large

white spot, which is the nucleus.

In the *pigmentum nigrum* from the eye of an adult human subject (Fig. 152, B), the cells are much larger than those in the *Sheep*, and the granules also more

plainly seen. In Albinoes, that is in the white offspring of black parents, the hexagonal cells are present, but

FIG. 154.



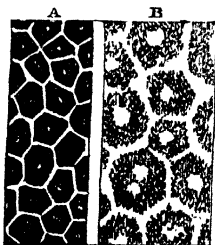
A, pigmentum nigrum of a black *Rabbit*. B, cells from the choroid of a white *Rabbit* in which the pigment is wanting.

the pigment is so small in quantity as to allow the vascular choroid to be seen through the pupil, giving a pink appearance to the eyes of these people. The same may be said of white *Rabbits* and *Cats*. A portion of the pigmentum of the choroid of a black *Rabbit* is represented in Fig. 154, A, the

cells are full of granules, and similar cells from a white *Rabbit*, in which the pigment-granules are either absent or void of colour, are shown at B; the eyes of these animals are, from this circumstance, more or less pink.

In the *pigmentum nigrum* from the eye of a foetus,

FIG. 155.



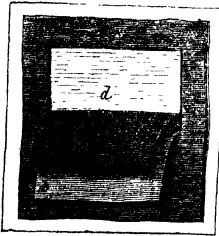
Pigmentum nigrum from the eye of a human foetus: A, cells magnified 250 diameters. B, portion of the same magnified 600 diameters.

the cells are not only smaller than those of the adult, but the granules also are fewer in number, and the centre of each cell is occupied by a large white spot, the nucleus. A portion of this pigment, as seen under the same magnifying power as that of the adult, in Fig. 152, B, is represented in Fig. 155, A, and

in order to show the nucleus and the granules, the portion B is magnified six hundred diameters.

I shall next describe the pigment developed in the skin, but must first state, that, until the last few years, a coloured layer, distinct from the cuticle, and termed

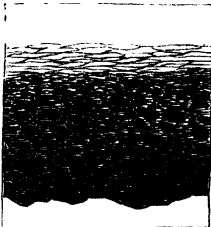
FIG. 156.



A portion of the skin of a Negro: *a a*, cuticle; *b*, portion of cuticle reflected; *c*, layer termed *rete mucosum*; *d*, true skin.

termed *rete mucosum*, is shown; while in the other, which is the skin of a European, a similar layer, unstained with pigment, is turned down; these layers,

FIG. 157.



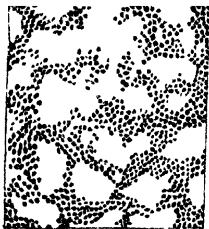
Vertical section of cuticle of the Negro, showing that the last formed cells contain most pigment.

rete mucosum, was supposed to exist in the skin of the Negro; a similar layer was subsequently found in the skin of the white man, but devoid of colour. In two preparations by Hunter, the one, the skin of a Negro, represented by *a a*, in Fig. 156, in which, in addition to the cuticle *b*, the black layer, *c*, however, are nothing more than the last formed portions of the cuticle.

The vertical section of the skin of a Negro, Fig. 157, serves to show that not only the cells, but the pigment also, is most abundant in the deepest layer, and, as you ascend towards the free sur-

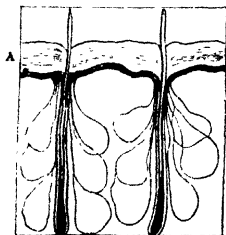
face, the pigment decreases in quantity, and the cells become flattened into the form of scales, from which the pigment is absent. A portion of the cuticle of a Negro with its inner or attached surface uppermost, which has been dried before being mounted in Canada-balsam, exhibits cells of a more or less hexagonal figure, containing the pigment. In another specimen from the same skin, Fig. 158, the disposition of the cells is better

FIG. 158.



Pigment cells on the under surface of the cuticle of a *Negro*.

FIG. 159.



Vertical section of the skin of the nose: A, cuticular layer having a band of pigment on its attached surface. B B, hairs and sebaceous follicles.

shown. The preparation is mounted in fluid; and it may be noticed that the surface is pitted, and that the greater part of the pigment-cells are arranged around the depressions, into which the papillæ of the true skin are received, these depressions being the white parts of the figure.

A vertical section of the skin of the nose having a stratum of black pigment in the deepest portion of the cuticle, while the upper part is quite white, is represented in Fig. 159. The specimen is interesting in another point of view, as several hairs, B B, are visible in the cuticle, each having seba-

aceous follicles on either side; many of these follicles are enormously dilated, and within them a quantity of dark granular matter is contained, thus affording a good example of one of the forms of the disease called *acne*, which essentially consists of an enlargement and suppuration of the sebaceous follicles. The colour of the hair frequently depends upon the pigment developed in the cuticle; and it is a well-known fact, that in those animals, as the *Pig*, in which there are occasional patches of black hair, the skin from which such hairs grow is generally black; so, in the Albino, the hairs are white, because no pigment is secreted.

Pigment is developed in peculiar situations under certain circumstances, as around the nipple during pregnancy, and in certain spots on the face, called freckles, after exposure to a summer's sun; in both these instances the colouring matter disappears on the removal of the exciting cause. Pigment is secreted by the *Cuttle-fish* in a special gland, termed the ink-bag, and this pigment is largely employed by the artist, under the name of *sepia*. Pigment is also secreted in cells in certain states of disease, as in *melanosis*—a striking specimen of which in both ovaries of a female is preserved in the Museum. In the lung of a *Calf*, here and there, a lobule is quite black, whilst all the others are perfectly white. A section of one of these black lobules, demonstrates that the pigmental matter is deposited in the form of irregular granules in the parenchyma of the lung, and such lobules

would no doubt receive nearly if not quite as much air as the whiter ones.

There are some rare instances in which pigment is secreted in large quantities on the skin of the human face. A remarkable case of this abnormal secretion of pigment is described and figured by Mr. Teevan in the "Medico-Chirurgical Transactions" for 1844.

I possess some pigment given me by Mr. Squire, the distinguished chemist in Oxford Street, which appeared under the right eye of a young woman, and was capable of being brushed off with a camel's-hair pencil. This is contained within cells like those of epithelium, and consists of granules. Mr. Squire tried various experiments upon it, and found that he could not remove the colour either by the strongest acids or by chlorine.

Having now arrived at the period when my labours, for the present session, must be brought to a close, it only remains for me to thank you most sincerely for your kind attention, and to express a hope that I may, in some measure, have succeeded in imparting such knowledge as may be useful in the practice of your Profession; and if so, I shall feel that I have accomplished one of the great objects for which this Institution was established, viz.: the advancement of those sciences conducive to the alleviation of human suffering, and the good of mankind.

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